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Adiuvantibus

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DIFFERENCES OF DYNAMISM OF KARST-FORMATION PROCESSES IN MICRO-AREAS

by

DR. L. JAKUCS

The climate is known to be of decisive importance in the regulation of the intensity of karst-formation. In the course of our earlier studies wide-ranging arguments were presented, justifying the placing of the climatic variances of karst-formation at the centre of morphogenetic analysis.

It can safely be said that the karstic corrosion of limestone rocks is essentially a formal reflection on the soluble base-rock of the phenomena of the biological and chemial development of the soil covering the rock. At the same time, however, it is an important condition that, as regards their extents and natures, these biological and chemical developmental phenomena are decisively of a climatogenetic regulation.

The simple reason for the manifold quantitative and fundamental qualitative differences in the karstic denudation of limestone areas with the same lithological, tectonic and orographic characteristics, but belonging in different climatic zones, is that these areas differ with regard to temperature and precipitation; because of this, specific vegetation types live on their surfaces and various soil biological, and hence chemical, processes occur.

The results of Hungarian and international research in recent years convincingly attest to this argument. It is time, therefore, to make the next step. If it has proved true that differences in the volume of precipitation and in the temperature (mainly by biochemical transposition) give rise to differences in the dynamism of karst-formation in the comparison of geographically widely-separated regions, *then it must also be true if a comparison is made between regions with different climatic features, which are not widely separated geographically.* That is, the distance can play no part at all in the process.

In other words, this means that *the karstic process in a given micro-area is always determined by the microclimatological characteristics of the area in question,* while these are functions of not only the macroclimate of the region.

The planetary zonality of the macroclimate is manifested in the karstic process in so far as it determines the features and proportions of the individual microclimatic areas within the climatic region. If the different local conditions of orography, exposure, wind-shelter, etc., within a given macroclimatic region produce a micro-area with extreme microclimatic properties, the qualifying factors of which differ appreciably from those general for the climatic zone, then the local intensity of the karstic processes will also differ considerably from that of the overall karstic process characteristic of the macro-area (region). The intrazonal appearance of *(the)* most of the karst-morphological, extra-zonality features is connected with this. *In a zone, therefore, the nature of the process of denudation of the surface must be interpreted as a statistical mean proportional of the concrete, not necessarily similar denudation processes of the numerous micro-areas forming the zone.*

It is obvious that this finding does not refer only to karstic denudation, but in accordance with the aims of this paper the question will here be analysed further only in this respect. It is subsequently most important to establish the smallest physical-geographic regional units for which the differences in microclimate producing the differences in intensity of karst-formation may still be expressed in form.

It is interesting that the synoptic study of this field from the aspect of the geomorphologist has not previously been initiated either in Hungary or abroad. For this reason, apart from our own investigations it is necessary to rely on the results primarily of certain pioneering climatologists, pedologists and biologists, obtained in analyses with quite different aims. Perhaps the most important of these are the researches of WAGNER, which, in addition to the exact conceptual clarification of microclimates of various magnitudes, provide a tremendous amount of valuable observation material on karst regions, relating to long periods of time, for the assessment of the possible morphogenetic connections (WAGNER 1954, 1955/1—2, 1956, 1960, 1964, FUTÓ 1962, BÁRÁNY 1967, etc.). However, the soil respiration studies of soil scientists (in this respect primarily FEHÉR [1954]) are also extraordinarily significant, as are those phytocoenological researches which analyse the plant-association types of a karst region of homogeneous rock material in a microclimatic interpretation (BACSÓ—ZÓLYOMI 1934, JAKUCS 1954, 1955, 1956, 1961, 1962).

Due mainly to the above authors, we know that there are very considerable microclimate-genetic soil-intensity differences for example on the karstic surfaces of mountains of medium height, and not only in the rhizosphere processes of the characteristic forest associations, shrub-forests and steppe-meadows accompanying slopes of a northern or southern exposure (thus, for example, even within a single dolina), but in even much smaller area-mosaics than this (for instance, in the root-crowns of two plant species living immediately adjacent to one another). This refers particularly to the mutual relation of the soil respiration and the production of carbon dioxide in the soil, which depend very sensitively quantitatively on the activity of the soil microorganisms. However, it is just these which are the most essential aggressivity-determining factors as regards the ability of the water percolating from the soil towards the karst to develop the karst.

Thus, if it can be proved that, for example, there are differences of a microclimatic sense, but of a considerable magnitude, in the quantities of heat, in the courses of the heating-up and cooling-down curves, in the amount of precipitation, in the soil moisture, etc. of dolina slopes of northern and southern, and of eastern and western exposures, then as postulate these entail differences in the natural vegetation living on them, in the bacterial flora in the related pedosphere, and also in the soil aeration, etc.; the partial dynamic division of the karstic process within the dolina then follows clearly from this. That is, the corrosion denudation will of necessity be of a different value on the dolina slopes of different exposures. From this condition, the conclusion may readily be drawn that *the form and aspect of the karstic dolinas are a formal reflection of the organization of their adequate microclimatic areas.*

In the following we shall examine some of the premises of the above argument, which was formulated only as a working hypothesis.

WAGNER reports series of measurement data on the microclimate of one of the dolinas of Középbérc on the Bükk plateau, which are more detailed than the earlier sources (BACSÓ—ZÓLYOMI 1934, LÁNG 1953, GEIGER 1961, FUTÓ 1962). These data give an accurate indication as to the measure of the characteristic temperature differences and the tendencies of these in the interior of the dolinas (WAGNER 1960, 1963, 1964, AMBRUS 1965, GÖMÖRI 1967). It is shown that in Hungary the slopes of the dolinas which heat up the most intensively and for the longest periods of time are those of south-eastern or southern exposure, while the sides of north-eastern or northern exposure remain the coolest. *If the eastern and western exposures of a dolina are compared, however, the sides facing the east are always the warmer.*

The differences in temperature of the opposite slopes become particularly evident in the early morning hours, when in summer the temperature differences in the air layers close to the soil of the eastern and south-eastern exposures moy be 10 °C or even more. In the afternoon, however, when the western slopes receive direct irradiation, the inversely compared temperature differences remain lower.

The variations of the amount of heat and the heating-up during the day show up more perceptibly for the southern and northern exposures, but in addition to this for the eastern and western exposures, in the comparison of the *soil temperatures*. Figure 1 gives the observations of four soil-climate stations placed in four different exposures of a dolina, referring to a soil-depth of 2 cm.

Naturally, the differences in inclination of the slopes are reflected primarily by the magnitudes of the amplitude, but the characteristic courses of the heating-up curves, particularly of the eastern and western exposures, the shift of the positions of the maxima, and the steepness of the heating-branch of the diagram, also partially involve the features of other factors causing the more extensive continentality of the eastern slopes.

The complex assertion of several factors must be seen in this relation. Of these, only a few will be mentioned:

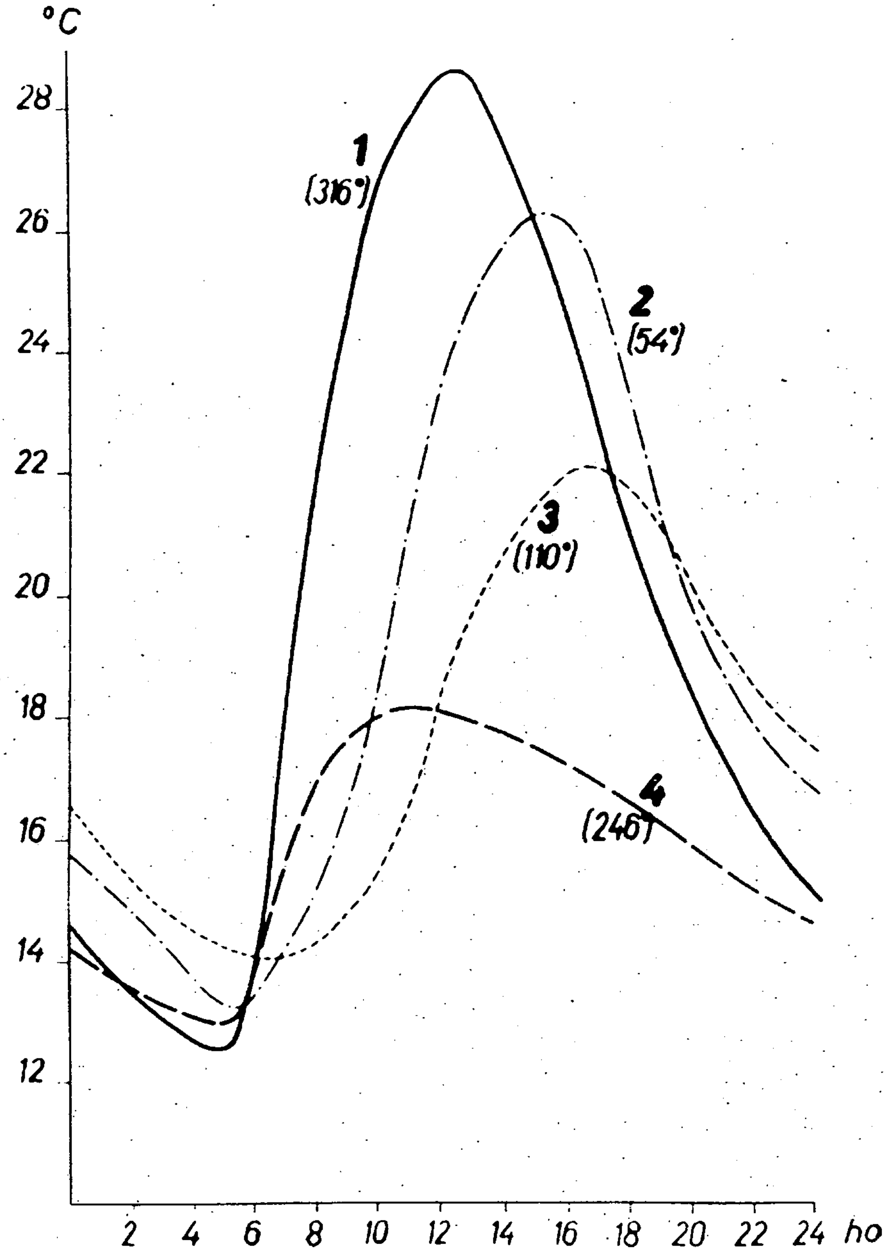


Figure 1. Soil-temperature curves, measured for a depth of 2 cm, from soil-temperature stations with different exposures in a dolina at Középbérc in the Bükk mountains. The 24-hour temperature diagrams were prepared from the average values of the observations of WAGNER for four consecutive cloudless days (6, 7, 8, 9th August, 1965).

1. In summer there is generally less cloud in the morning hours than in the afternoon.

2. Already in the early morning the eastern exposure receives by direct radiation the amount of heat which is of such decisive importance for the heating-up of the soil. During this same period the soil of the western exposure heats up very slowly by means of conductive heat transfer from the air, with its low specific heat. In the afternoon hours, however, when the western exposure receive direct irradiation, cooling-down of the eastern slopes by emission of heat can proceed only slowly, since the air in contact with the soil is strongly heated during the day. The eastern exposure is thus hot continuously throughout the complete period of irradiation, whereas the western exposure is hot only in the afternoon.

3. The frequency of summer showers is higher in the afternoon than in the morning. Because of this, in the intensive heating-up of the western exposures the thermal content of the direct irradiation is more frequently used for evaporation than on the slopes of eastern exposure.

4. The angle of incidence of the precipitation is controlled by the wind-direction prevailing at the time of the rainfall. This is usually a W—NW wind, and thus the eastern and south-eastern slopes receive statistically more precipitation than western and north-western dolina slopes of the same inclination.

The characteristic daily courses of the soil temperatures of the various exposures not only affect the soil at a depth of 2 cm, of course, but also determine the heat economy of practically the total active soil profile. The pedosphere processes of the dolina sides of eastern and southern exposure will thus always be more extreme than those of the sides of western and northern exposure. This can be perceived particularly well in the daily temperature fluctuation of the soil at a depth of 30 cm, where a variation of temperature can hardly be observed for the soils of the western exposures.

The above, very considerable differences in temperature, precipitation and heating-up within a dolina act in multiple connection on the CO_2 production of the soil of the dolina, on the intensity of the soil respiration, and heating-up within a dolina act in multiple connection on the CO_2 of microflora and fauna of the vegetation and the soil, and via all these on the karstic process itself in the long run, and on its local differences of dynamism.

For example, the moisture contents of the soils of dolina sides of various exposures are among others unmistakably connected with the extent of irradiation and the degree of heating-up. This is documented, for instance, by the results of our detailed dolina-recordings in a vegetation-free dolina (about 1300 m NNE from the bell-tower of the Protestant church in Jósvafő) of the Északborsodi karst; the vegetation-free state of the dolina at the time of the study (May, 1962) was the result of ploughing. The results of the determination of the moisture content by the drying-out of samples collected from the soil level at a depth of 10 cm are shown in Figure 2 in an interpolated form.

It has so far been confirmed that even within a single dolina there are very marked differences of soil temperature and soil moisture, and

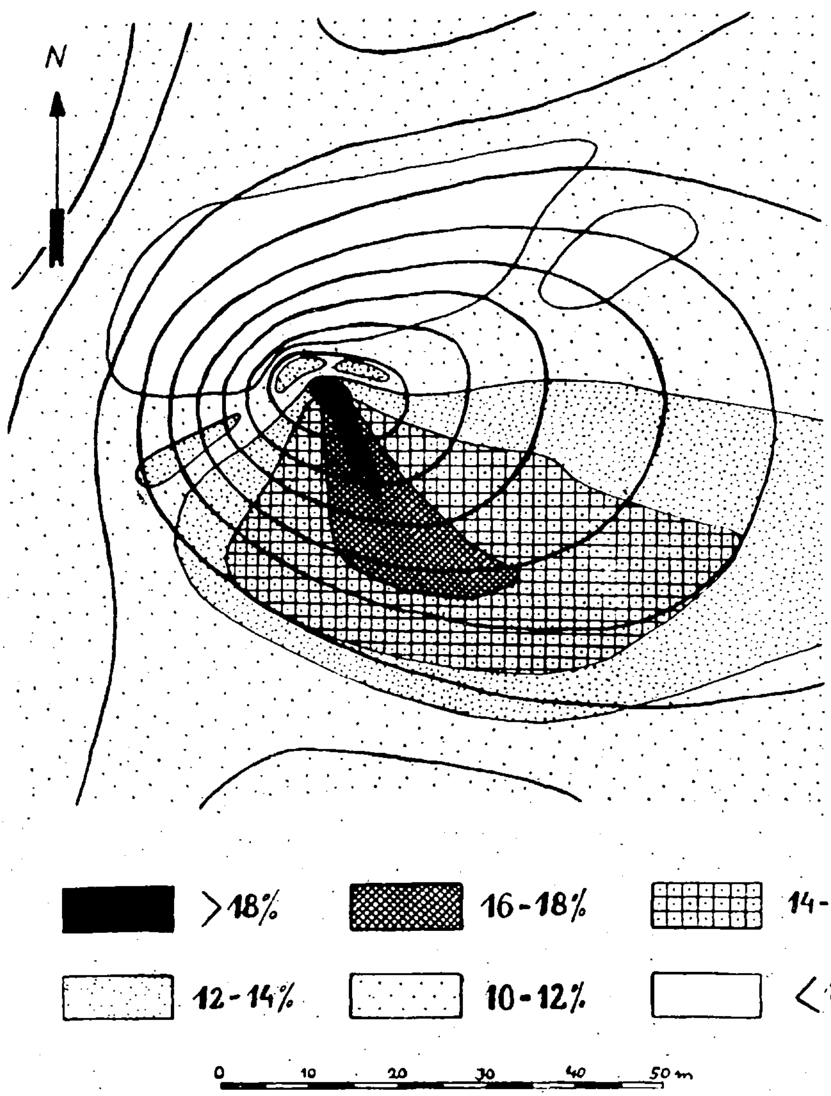


Figure 2. Example of the distribution of the moisture content of the soil at a depth of 10 cm in a vegetation-free (ploughed) dolina with uniform soil-quality. The values of the soil moisture are expressed as weight percentages. The contour lines depict the 1 m isohipsae. The chart was interpolated (according to a 10 m square mesh-grid) on the basis of 81 observations (original).

that these factors are related with the points of the compass. The further development of the chain of thought in the direction of the proof of the microclimatic regulation of the differences in dynamism of karstic corrosion is already quite apparent.

One of the fundamental precepts of biology, on a text-book level, is that the life-furctions of microorganisms living in the soil react sensitively to changes of the soil temperature. In 1926 RUSSEL published a diagram clearly depicting the sensitive fluctuation of the number of bacteria in the soil with the daily course of the temperature (Figure 3).

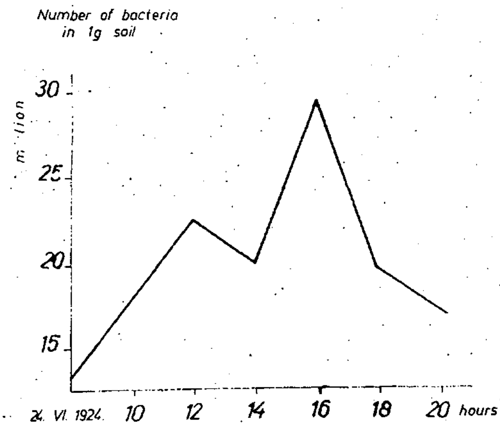


Figure 3. 12-hour variation of the number of bacteria living in the soil as a function of the daily course of the temperature of the soil level studied (observations of RUSSEL [1924]).

Based on extensive series of experiments and observations, however, FEHÉR (1954) also points out that in itself the optimum temperature is still not a sufficient criterion of the stimulation of the population of a soil microorganism; this can be ensured only by the synchronous occurrence of the temperature and soil moisture optima. According to his investigations, which were recently supported by those of BECK (1968), the crucial optimum for the virulence and multiplication of the bacterial flora in the soil is ensured by a temperature of 25 °C, with a simultaneous soil moisture content of about 25 wt.%, naturally under adequate soil-aeration conditions. The decrease or increase of any of these factors immediately results in a strong decrease of the number of bacteria. The extents of the correlations can be estimated numerically from Figure 4.

Under the climatic conditions in Hungary, the variations of the temperature and moisture content of the soil generally develop antagonistically. In summer, when the temperature attains the optimum values, the water content of the soil is usually low. Even when it is temporarily higher at the time of a more considerable precipitation, the higher temperature again impedes the optimum development of the bioactivity by providing the heat required for evaporation.

Because of the considerable exposures of the dolina sides, this antagonism which is characteristic of the Hungarian climate appears still more markedly in the dolinas. For this reason, in the soil of the dolina slopes of eastern and southern exposure, which heat up rapidly and srongly, there will be shorter periods when the temperature and moisture conditions are almost optimum for the bioactivity (the strong insolation following night or early morning rains in summer). At such time the sudden increase in the number of bacteria and the accompanying enhancement of the CO_2 production in the soil lead to the peak values extremely quickly. In general, however, as regards the conditions of existence of the microorganisms the effects of the higher quantities of heat are adversely affected by the often prolonged, strong drying-out of the soil in summer, and because of this on slopes with such extreme amplitudes of temperature and soil moisture the bioactivity and hence the intensity of karstic corrosion also exhibit very wide fluctuations.

In contrast with this, we have seen that there are no such similar extremes of either temperature change or moisture content in the soils of dolina sides with northern or western exposures. The generally lower, but more even temperature course and the more significant soil moisture do at times exhibit different degrees, but they definitely ensure a more settled soil microorganism level. In implicit form, therefore, this has already been used to point out the perhaps most decisive cause of the less fluctuating, but weaker tendency to corrode, which is characteristic of the soil waters of the exposures in question.

In connection with this, it should be noted that in the morphogenetic effect arising from the differences in exposure of the dolina sides WAGNER lays great stress on the insolation factors disintegrating the rocks, this process being more pronounced on the rocky slopes with eastern exposure which heat up rapidly, and on the physical disintegration factors involved in the possibilities of more intensive lithoclase formation due to the movements of expansion. However, there have so far been no concrete investigations on the limestone dolina sides to confirm this very realistic-seeming conception, and thus his view must for the present still be regarded as a working hypothesis regarding the extent of the morphological assertion of the factor.

Naturally, the discussed microclimatic exposure characteristics in a dolina are not only essential quantitative and qualitative determinants of the phytoedaphon, but also permanently favour the structure of the macroflora. For example, steppe-meadows rich in forest-steppe species (Festucetum sulcatae) occur on the (usually rocky) slopes of southern exposure in the unwooded dolinas in the Bükk mountains (Hosszúbércirét, Kismező, Nagymező) or on the Északborsodi karst (Verőtető, etc.); in contrast, mesophil mountain meadows (Festucetum ovinae) can be found on the eastern and western slopes and in general on the rim too (if the soil is not deep); on the northern slopes either the former or hazel

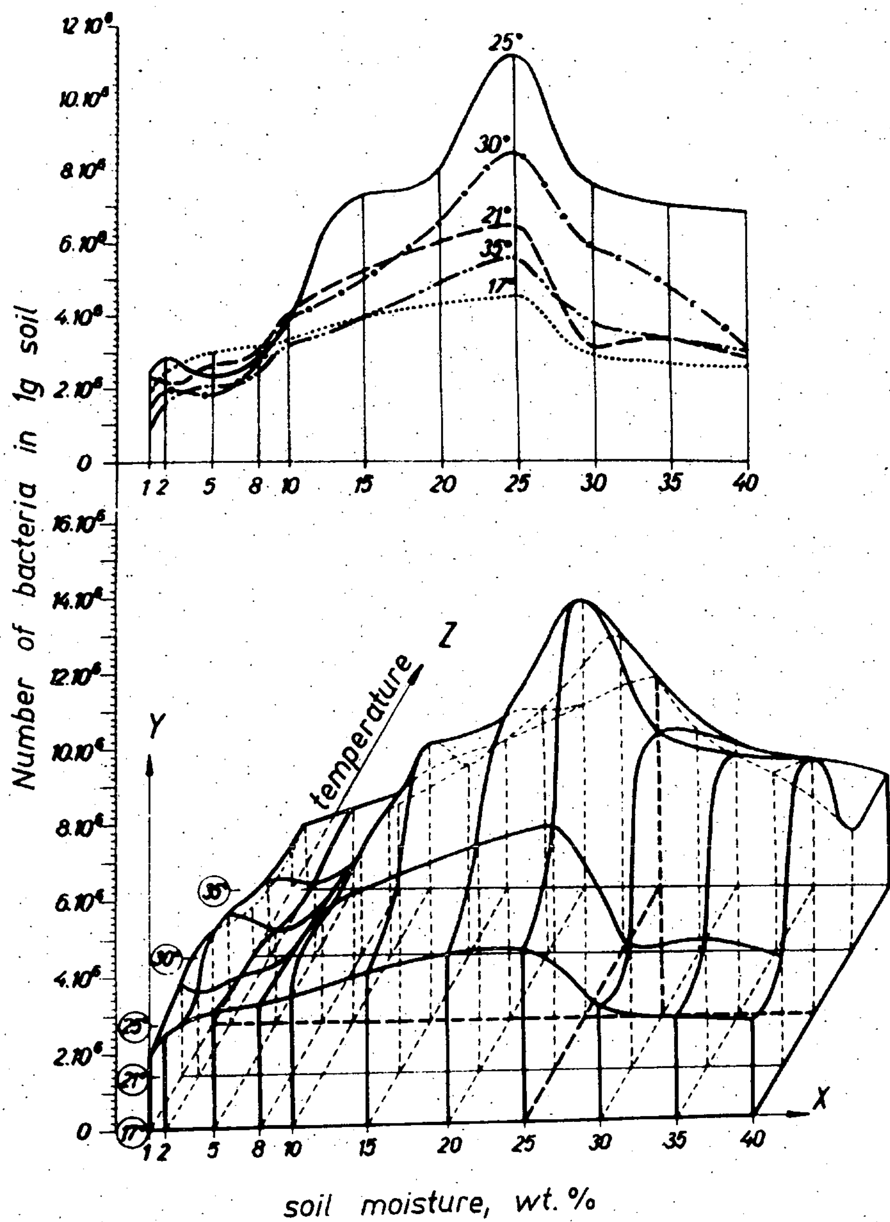


Figure 4. Spatial curve demonsrating the bioactivity of the soil, from which the reflection of the complex effects of temperature and moisture on the number of soil bacteria can be read off numerically. The X-axis gives the soil moisture in weight %, the Z-axis the soil temperature in °C, and the Y-axis the number of bacteria referred to 1 g soil. The upper diagram gives a projection of the curves in the X—Y plane (after FEHÉR).

groves occur (if rockier: Coryletum avellanae); and on the flatter parts with deeper soil, such as the shoulders and the bottom of the dolina mat-weed swards (Nardetum strictae) occur. If the bottom of the dolina is rocky and funnel-like, then high, dry-stalked vegetation may develop there (Aconitum, Gladiolus, etc.) (JAKUCS 1961/1—2, 1962). These plant-associations exhibit inversion zonation in the dolinas.

Such a vegetation inversion has otherwise been demonstrated by GEIGER (1961) in the Lower Austrian Gstettneralm dolina, and by HORVÁT (1953) in dolinas of the Yugoslav Karst mountains.

It is obvious that other associations are found in other vegetation zones (altitude zones), and the situation is completely different even in a wood-covered dolina. However, the differentiation according to exposure is characteristic there too. Via pedosphere transposition, all this has a great effect on the subsurface karst-formation, since the demands of the various plant species towards the soil differ, as do the effects on the development of the soil and on its state as regards its chemistry, its microorganisms, its moisture, its aeration, etc.

For abvious reasons, these relations have still not been examined in magnitude with regard to the association types of the natural flora living on the karsts, but as regards the agricultural plants and some other, mainly tree species, series of relevant concrete results have long been available. Table I (after STOKLASA—DOERELL [1926]) shows the CO_2-productions in the soil the soil of six agricultural plants and four soil bacterium species; the amounts of CO_2 formed correspond to 1 g dry weight of the roots or bacteria.

TABLE I

plant or bacterium	24-hour CO_2 production (in mg CO_2)
sugar-beet	0,3 — 5,4
barley	63,2 — 74,6
wheat	87,6 — 94,8
rye	100,7 — 131,0
oat	111,5 — 135,4
buckwheat	212,5 — 274,0
Clostridium gelatinosum	480
Bact. Hartlebi	600
Azotobacter chroococcum	1270
Bacillus mesentericus	13000

It is immediately seen from the Table that from the point of the edaphic CO_2-production the bacteria (but microorganisms in general) are of much greater importance than the plant roots. The fact that despite this there is an unmistakable connection between the formation of the root-karr channels and certain plant species in the karst vegetation (e.g. Nardus stricta) (JAKUCS 1956) is in our view probably connected with the phenomenon that bacterium populations of different species live in different numbers in the root zones of the various plants; indeed, partly in symptomatic relation with this, the local soil moisture concentration in the rhizosphere (particularly in an arid period) points to the adequateness of a plant species.

The importance of this connection between the plant roots and the number of bacteria in the soil was determined quantitatively by THOM and HUMFELD (1932) (see Table II).

TABLE II

	number of bacteria in 1 g soil	number of fungi in 1 g soil
in soil without roots	5 500 000	100 000
in the rhizosphere in general	26 000 000	800 000
n the immediate vicinity of the root-hairs	136 000 000	7 000 000

Since the carbon dioxide production of the soil depends very strongly on the edaphon amount (FEHÉR 1954, GEIGER 1961, FEKETE 1952, 1958, STEFANOVITS 1963, FEKETE—HARGITAI—ZSOLDOS 1964, BECK 1968), on the above basis it is almost necessary that there should also be considerable differences in the amounts of carbon dioxide produced by soils of different flora-cover (and hence different homus content) and of different vegetation type. That this is in fact so has been confirmed by the now classic observations of STOKLASA and ERNEST (1922). Some of these data are given in Table III, with the note that although these observations do not refer to karst, similar tendencies are exhibited on karsts.

By comparison with Tables I and II, it is immediately obvious that the ability of the roots of certain plants (together with the related phytoedaphon) to corrode limestone will be many times larger than that of some other plant living in the same area (e.g. in a dolina), the rhizosphere of which requires a bacterial symbiosis differing both quantitatively and qualitatively. Thus, the question raised at the beginning of this paper, as to which are the *smallest* natural geographical area units for which the microclimatic genetic differences inspiring the differences in intensity of karst-formation can still be formally expressed, can have only one answer: *there are no such smallest magnitudes.*

The reason for this is that in the subsoil karst-formation, where the normal surface planation processes (wind, water erosion, etc.) which otherwise ensure areality can not play a role, even within the smallest area innumerable minute faults with different denudation dynamics exist in direct proximity to one another. These may be of the order of a square metre, a square centimetre, or a square millimetre. *In these sometimes infinitesimally small micro-areas, which are differentiated in their degrees of corrosion, characteristic adequate solution microforms develop, which*

TABLE III

Carbon dioxide productions of various types of soil (after STOKLASA—ERNEST)

type of soil	depth	amount of CO_2 produced (mg) in 24 hr from 1 kg soil at 20°C
adobe	surface soil	49,7
adobe	subsoil	7,6
calciferous	surface soil	18,5
calciferous	subsoil	9,8
marsh	surface soil	41,2
forest	surface soil	36,4
forest (humus-poor)	25 cm	9—12
forest (humus-rich)	25 cm	20—26
pasture	25 cm	10—16
barren (humus-poor)	25 cm	8—14
good rye and wheat soil	25 cm	30—48
good clover soil	25 cm	53—60

in their sum total then form the traditional karst-morphology form-types, such as the karr-field, the dolina, etc.

Of course, it would be quite erroneous to draw from this any conclusion such as that the development, character and arrangement of the macroforms on a karst come about only from the statistical sum of the partial processes of the microfacies. In reality the reversible assumption also acts in the opposite direction: the criteria and proportions of the microclimates and association-units and the arrangements of occurrence of their types are determined by the zonal macroclimate of the area, by its petrological nature, and by its topographical, tectonic, hydrographic, etc. variances. *That is, although the corrosion processes themselves do proceed in the mosaics of the micro-areas, these mosaics fit into one or more larger systems, and the characteristic features of such systems are no longer qualified by the mathematical sum of the partial processes of the mosaics.*

Methods of studying the CO_2 contents of gas mixtures from micro soil areas

We have seen that the investigations most closely approaching our problem arose from researches not of geomorphologists, and even less of karst-morphologists, but primarily of agronomists, pedologists and biologists. It is natural, therefore, that the data do not refer to the undisturbed soil and vegetation processes of karst and their CO_2-production correlations, but are concerned in fact mainly with cultivated plants. The few references in the karst-genetic literature (TROMBE 1951/2 1952, 1956, SMYK—DRYZAL 1964, etc.) too are either based on only one or two measurements, or generalize observations in the pedological literature arising from other pedofacies. And although this dependence on analogy (while we can not rely on series of measurements concretely for karstic regions) is completely self-evident, and indeed can also provide reasonably good results, an effort nevertheless had to be made to provide an answer to the problem on the basis of researches into the problem itself.

However, this was not an easy task, and the series of investigations which have been begun have by no means been completed. A particular difficulty was caused above all by the fact that we ourselves had to develop suitable methods of research. The methods applicable at present to the recording of soil respiration and permitting the analysis of the soil atmosphere could not be used in our case.

It is well known that the proportion of CO_2 in the soil air is generally determined by taking a sample from the undisturbed soil by means of a suitable apparatus (most often with a metal cylinder with a sharpened rim, containing a volume of 1 litre), then transporting the sample to the laboratory (excluding the possibility of exchange of the air), expelling the soil air from it with water or a 10% solution of common salt, and collecting the air bubbles with a funnel. The soil air thus obtained is then analysed for its CO_2 content by absorption in potassium hydroxide solution in the ORSAT smoke-examination apparatus, or by the GORBUNOV barium hydroxide (hydrochloric acid titration) method (BOROVJEV—JEGOROV—KISELJEV 1951, di GLÉRIA—KLIMES—SMIK—DVORACEK 1957, BALLENEGGER-di GLÉRIA 1962).

If it is desired to establish the extent of CO_2-production of the soil in unit time, the course of the analysis is modified as follows: a slow current of air is sucked through the soil samples in the laboratory, the carbon dioxide contents being measured both on entry and on exit (via absorption, by volume or weight analysis or titration), and the difference between the two is used to calculate the CO_2 content referred to the measurement time and the amount of soil used in the experiment.

In another procedure a metal bell, closed from the side and above and prepared for this purpose, is pressed to a certain depth into the soil; the air expired under the natural conditions from this is collected in the bell, which is next connected to an appropriate apparatus (e.g. the LUNDEGARDH apparatus), and the amount of CO_2 absorbed by the $Ba(OH)_2$ is determined by the above-mentioned method of titration with hydrochloric acid (BALLENEGGER 1953, FEHÉR 1954).

We too carried out our first investigations into the CO_2 content of karst surface soils with the above method, but the time and laboratory requirements of these procedures induced us to develop a more rapid method of measurement which could be employed on the spot. In addition to attempts to use the time more profitably, this was also induced by other aspects. It was observed that the time between the taking of the soil sample and the performance of the laboratory work is of great importance as regards the CO_2 content of the soil air. Of soil samples of the same nature, collected from under the same vegetation at the same time and immediately adjacent to one another, that one was always found to contain significantly more CO_2, from which the air was expelled latest. This is otherwise understandendable, since nothing justifies the stopping of the biovegetative and other oxidative processes to the extent of the oxygen-reserve of the atmosphere in the hermetically sealed soil sample. In serial examinations, however, where the comparison is the essence, this circumstance means that the method is of practically no use.

If it was desired to measure the extent of the soil respiration, the problems increased still further. By virtue of the nature of the matter, such a determination demanded so much time (according to the methods employed, the laboratory or field observation time necessary to record a single datum was at least 5—10 hours), that a statistically evaluable series could not be obtained by this means either.

Since our research aims required the comparison of the CO_2 contents of adjacent karst surface soil areas with different microclimates, and mainly in syncronism, it became unavoidable to develop a method of measurement which was rapid and could be performed on the site. Two procedures were elaborated for this purpose, and in the absence of any earlier publications in this respect, a brief account of these will be given below.

Method I. The soil gases are extracted by means of a thin copper probe, with an external diameter of 5 mm and the wall of which is perforated at the end. This can simply be inserted into the soil to the required depth. It should be noted that the lower end of the 40 cm long probe ends in a conical point, and a steel rod of the same thickness as the internal diameter of the tube can be slid into it. This rod is left in the probe when the latter is inserted into the soil, and must be removed from it only immediately prior to the extraction of the air sample. The tight-fitting steel lining serves partly to strengthen the thin-walled tube during the insertion, and partly to prevent the entry of soil particles into the probe through the perforations, but mainly to exclude the outflow of the soil air before required and the possibility of its admixture with other air.

Following the insertion of the probe, the surface of the soil within some dm^2 of the point of insertion is made impermeable to air; this is possible, for instance, by applying a film of thick oil (e.g. spent oil). (In the case of very porous, lumpy soils it is better to use melted paraffin or stearin.) The soil air is sucked out with a spring-motor or a small-current omtor (fed by a torch battery), specially constructed for this purpose, and connected to the above-ground end of the probe; the air is then led into an empty balloon (a football bladder proved very suitable) connected to the air-exit of the pump (see Figure 5).

After the extraction of about one and a half decilitres of soil air (depending on the air-permeability of the soil this requires 10—150 sec),

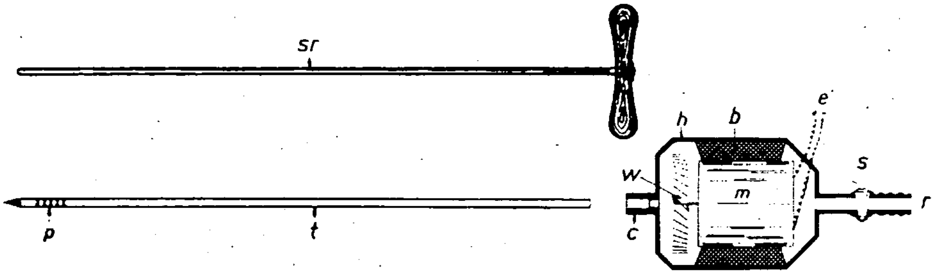


Figure 5. Principle of the soil probe constructed for the extraction of the soil gases (original).

t= thin-walled gas-extraction probe tube
p= perforation in the tube wall
c= air-tight cuff on the connection to the pump cose
w= 16-blade air-turbine wheel
m= small-current (12 V) motor (e.g. car windscreen wiper motor)
b= motor-support brackets
e= energy-supply leads with air-tight insulation
h= pump housing
s= stop-tap
r= rubber tubing
sr= steel support rod

the rubber tubing is clamped and connected to the ORSAT apparatus; the soil air is first used to flush out the apparatus, while a second filling is absorbed with a potassium hydroxide solution, which is then analysed by titration (Figure 6).

The method, which was first employed in 1965, can be carried out on the site, one person performing 4—5 determinations per hour. If it is wished to repeat the measurement at a later time (e.g. the following day), it is best to work with several probes and to leave the inserted probe in the soil during the period of repetitions.

In 1965 and 1966 this procedure was used to perform serial measurements in practically all of the karstic mountains of Hungary (Északborsodi karst, Bükk, Pilis, Gerecse, Bakony, Mecsek, and even in the Soproni basin at Fertőrákos). After the recording of some 300 measurements, it had to be recognized that although the differences in the CO_2 concentrations of the pore gases from the different soils and levels exhibit a considerable magnitude (several per cent) even, within small distances, while even at a given observation point the soil air space too is of high amplitude (depending on the time of day and other factors), there being very rapid changes of concentration at such times; nevertheless our data can still not provide a sufficient basis for the recognition of the regularities.

One of the possible reasons for this might be that the accuracy of the results is affected by the admixture of the soil air with the natural air present in the housing of the pump. This undoubtedly modifies the results, but at the same time the amount of normal air mixed in with

Figure 6. Study of soil air with method I on the Bükk plateau. The ORSAT gas-analysis apparatus can be seen in the right half of the picture, while on the left edge is the probe implanted into the soil, together with the attached suction head and the rubber tubing.

the sample is always the same (ca. 30 mm^3), and hence only the absolute values were modified, the ratios remaining relatively not affected.

However, the need to make the method more accurate was also justified from another aspect. The some 150 ml of soil gas absolutely necessary for the analysis was collected from the variable-diameter depression lens of the soil surrounding the perforated end of the probe, and the extent and form of this lens depended on the porosity factors and moisture content of the soil,. i.e. on unknown factors. Because of this, the method could not be used effectively to examine in particular the specific CO_2 productions of the rhizospheres of plant species living in direct proximity to one another.

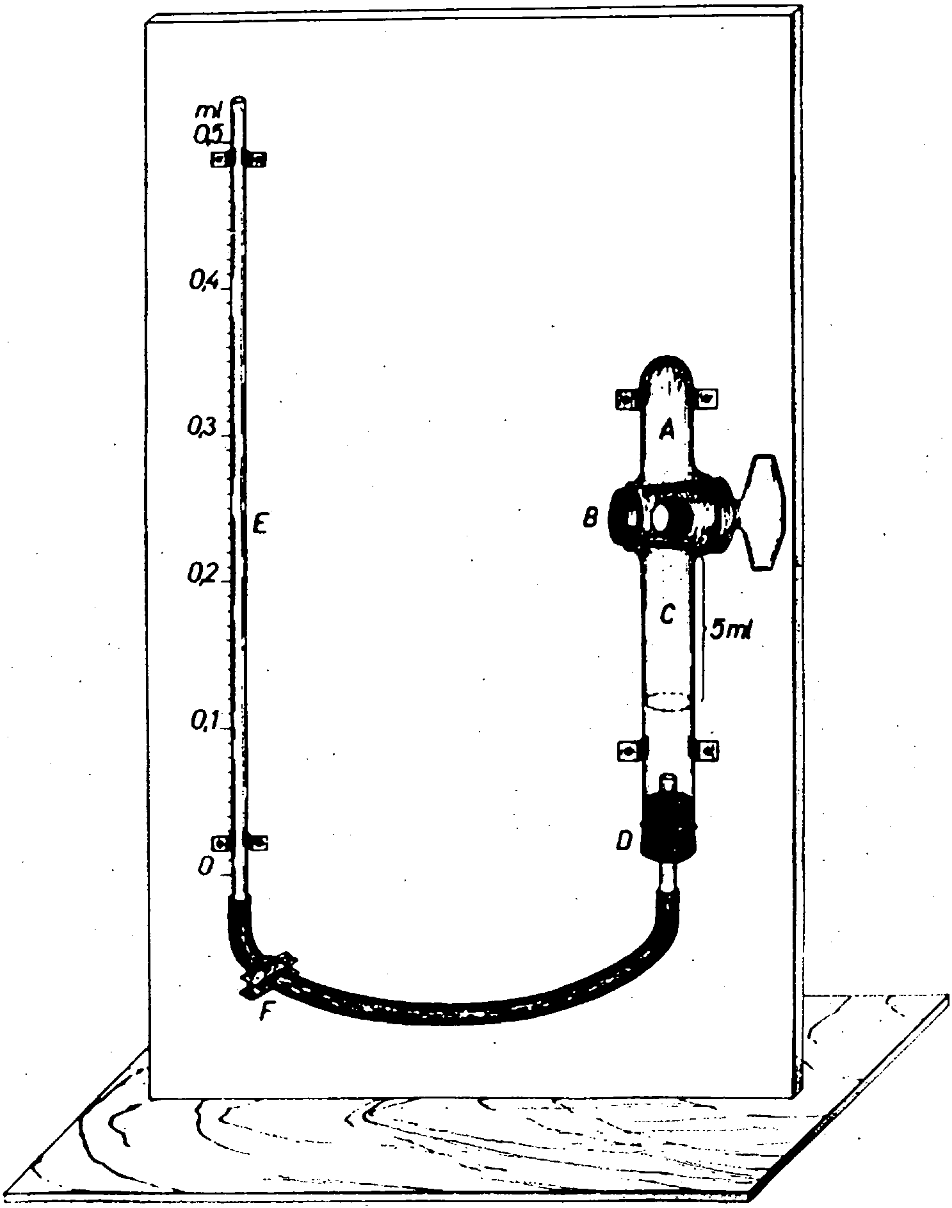
In order to surmount the above problems, therefore, a microanalytical method had to be developed, with which an accurate analysis could be carried out on a substantially smaller amount of gas. In this case controlled obtaining of a small quantity of gas from a planned locality can be much better ensured. The solution was found in 1967 in method II, described below.

Method II. The volume of the soil air sample required for the analysis was now only some 5 ml. This amount of gas is sucked out of the soil at the selected point with a PRAVAZ syringe. (It is advisable to ensure perfect fitting of the piston of the syringe with a coating of paraffin oil!) After insertion of the injection needle, the length of which is selected in accordance with the depth of the soil it is desired to examine, it is necessary here too to make the soil surface impermeable to air for a distance of about 20 cm around the point of insertion. It should be noted that during the insertion of the needle into the soil the mandrin must be left in it, and withdrawn from it only immediately prior to the connection to the syringe.

In our experience, if the soil is not extremely impermeable clay, or very miry, the extraction of the 5 ml of soil air generally presents no difficulty, and the diameter of the above-mentioned gas-depression lens is no more than a few centimetres. Thus, the extraction is localized to a well-defined pedosphere, corresponding exactly to the prescribed requirements (e.g. to the root zone of a single clump of grass).

The extracted air sample is analysed with the apparatus shown in Figure 7, according to the following:

The thick-bore ground-glass tap *(B)* divides the test-tube into two parts *(A* and *C)*. With the rubber stopper *D* removed, potassium hydroxide solution is poured into the test-tube, with the tap in the open position, so that *A* and the hole through the tap are filled with the solution and all air bubbles are excluded. (Concentration of KOH: 1 part KOH, 2 parts H_2O.) The tap is next closed, the KOH solution remaining in part *C* is poured out, and this part of the apparatus is then made free of alkali by repeated washing with water. Part *C* of the test-tube thus prepared is now filled completely with 10% NaCl solution dyed red or dark-blue, and the test-tube is inverted (mouth downwards) and placed in a flat glass bath containing the same solution. In this position, gas is



ml
0,5
0,4
0,3
0,2
0,1
0
E
A
B
C
5ml
D
F

bubbled into it from below out of the PRAVAZ syringe, until the coloured solution has been expelled from the test-tube down to the 5 ml mark on the wall of *C*. With its mouth still under the surface of the solution, the test-tube is stoppered with the rubber stopper *D*.

The glass tube in the stopper, the connecting rubber tubing and the calibrated capillary tube *E* too must also be filled with the coloured NaCl solution.

After the connection of the two parts of the apparatus, it is wiped dry on the outside, and fixed to a suitable stand in the position shown in Figure 7. The clamp *F* is opened, and the rubber stopper *D* is pushed a little further into the test-tube, so that the resulting weak excess pressure in *C* causes the capillary tube *E* to be completely filled by liquid. Any solution spurting out from the upper end of the tube *E* is carefully dried off with blotting paper, and when the upper end of the thread of liquid in the capillary tube has attained an equilibrium position (this sometimes requires 1—2 minutes because of the temperature-pressure equalization) the height of the meniscus is noted. Tap *B* is now. opened to permit communication between parts *C* and *A*. The potassium hydroxide solution trickles from *A* into space *C*, while the gas partially migrates from *C* into *A*. During this movement the CO_2 content in the gas mixture is absorbed. That is, the total volume of the gas and liquid-state phases in parts $A+C$ will now be less than the combined volumes of parts *A* and *C* before the opening of the tap by a volume corresponding exactly to the concentration of CO_2 in the gas mixture. The level of the liquid in the capillary tube *E* therefore falls in accordance with the loss of the CO_2 partial pressure.

If the capillary tube used is such that 0.5 ml liquid occupies a length of 50 cm inside it, then a fall of the meniscus by 5 cm corresponds to 1% CO_2. In this case, therefore, since a movement of 0.5 mm can be observed in the meniscus, the apparatus will be suitable for reading off directly any intermediate amount, up to a maximum CO_2 content of 10%, with a sensitivity of 0.01%. Naturally, depending on the bore and length of the capillary tube, scales which are more sensitive or less sensitive can be made.

When the measurements are carried out, however, particular atten-

Figure 7. Principle of the calibrated capillary-tube microanalytical gas-analysis apparatus (original).

A= potassium hydroxide reservoir

B= thich-bore ground-glass tap

C= reaction vessel consisting of an upper part with a 5 ml calibration and an uncalibrated lower part into which a stopper can be inserted

D= single-holed rubber stopper, fitted with a glass tube, the lower end of which is connected to rubber tubing

E= calibrated capillary tube for reading of observations, open at the upper end.

F= clamp

tion must be paid to one aspect: the apparatus reacts sensitively to even the slightest change of temperature. For this reason it is possible to work with the apparatus only in the shade, while that part of the vessel containing the reagents should be handled only with wooden holders, and should be protected from the heat of the hand and the breath.

With the necessary practice, the use of this procedure gives results quickly and accurately. It was employed in 1967 and 1968 to perform 940 measurements, the minority in Hungary, and the majority in Yugoslav karst regions. Since our researches on this theme will be completed only after several more years, a detailed account of the results gained so far will not be presented here. However, since they provide important information with regard to the understanding of the magnitudes of the karst-corrosion processes in the micro-areas, we shall now turn to some partial questions which can already be regarded as completed.

Examples of the characteristics of the CO_2-economy in the soil atmospheres of karstic micro-areas with different bio- and climatic-specifics

Even our first soil air examinations disclosed that, as regards the CO_2 concentrations of the soil gases, considerable differences are found not only between simultaneous measurements *at different positions*, but also between those for a given sampling point *at different times*. These are not only concentration level waves of large amplitude during the different periods of the year, as already described in the pedological literature (e.g. FEHÉR 1954), but gas composition changes of a much shorter period, which are nonetheless very appreciable. In the majority of cases, the same experimental result can not be observed twice, even at a given point.*

The above findings induced us, therefore, not to be satisfied with a large number of sporadic data, but to strive to compare homochronous series of data, if possible from a complete area of certain karstic forms (e.g. individual dolinas), and in addition to obtain material reflecting the tendencies of the happenings within longer or shorter time series at a specified observation point. For this reason, and particularly in 1968, measurements were generally made at one point at 2 or 1-hour intervals, during a period of one or several days.

These researches led to extremely instructive experience of prime importance, among others in one of the dolinas of a low, terra rossa limestone plateau lying to the south of the town of Karlovač in Croatia in Yugoslavia. Two needle probes were implanted into both the northern and the southern exposures of the dolina sides, one each at a depth of 5

* It should be noted here that in our experience it is necessary, when the 5 ml microanalytical method is employed, to ensure a rest period for the regeneration of the gas of at least one hour between two consecutive measurements.

cm and one each at 20 cm. The entire dolina was covered with fairly homogeneous vegetation: Pteridium aquilinum about 60—80 cm in height. On the two exposures where the stations were located the surfaces selected had the same slope (ca. 20°), and the sampling needles were implanted immediately beneath a Pteridium root. It was not possible to observe macroscopic differences in the soil composition on the two exposures, but the soil on the northern exposure was substantially wetter (even at the 5 cm level). (In the absence of the possibility of quantitative measurements, only estimations could be made in this latter respect.)

Figure 8 shows the variation in the CO_2 content of the soil gases on the first day of examination (14 July 1968), which was hot, unclouded and still throughout.

The daily concentration curves of the Figure referring to the indi-

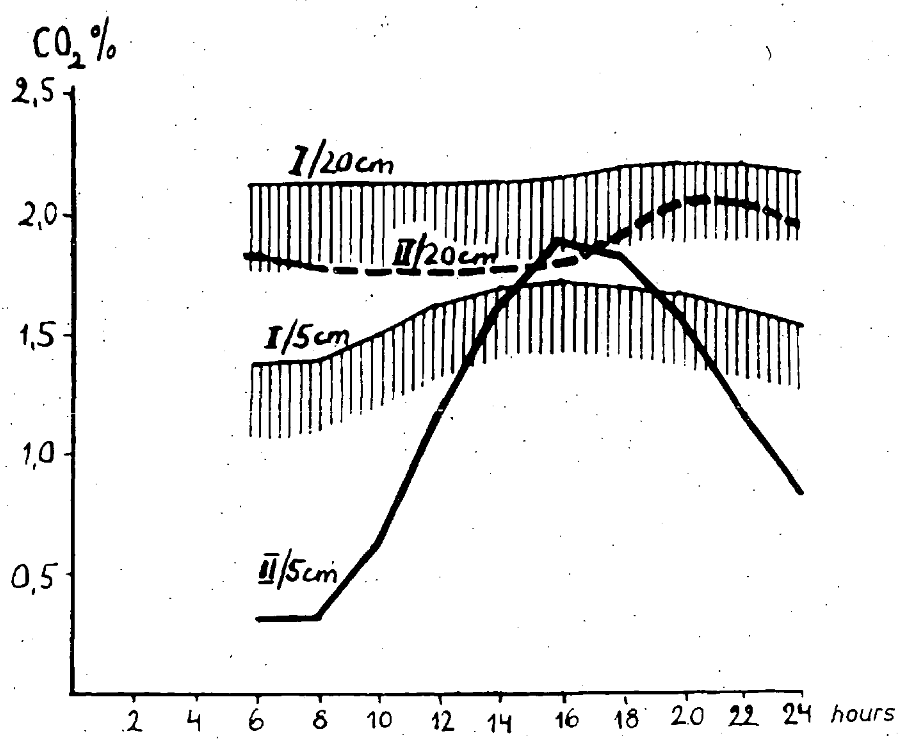


Figure 8. 18-hour variation of the CO_2 content of the soil air collected from the 5 and 20 cm levels under a well-developed Pteridium aquilinum plant on an unclouded, still summer day (14 July 1968). The measurements were recorded at 2-hour intervals on 20° slopes of northern (I) and southern (II) exposure in a dolina in Croatia (beside the main road leading towards Plitvice, about 12 km south of Karlovač). Type of soil: at 20 cm dominantly red-clay rendzina, and at the 5 cm level friable surface soil of mull type (original).

vidual points and levels give rise to the following findings, which, since no conflicting results have yet been obtained elsewhere, may perhaps be formulated already in a more generalized way.

1. The CO_2 content of the soil air in every layer of the studied exposures (in the karstic surfaces covered with vegetation) down to a depth of 20 cm exhibits *a daily course,* which adjusts itself sensitively and approximately linearly to the temperature curve of the soil.

2. The CO_2 concentrations of the soil gases at depths of both 5 and 20 cm fluctuate with much greater amplitudes in the southern than in the northern exposures.

3. As regards the daily average, the CO_2 proportions of both layers of the surface soil of the southern exposures are less than those of the nothern exposures. (It will be seen later that this point is valid only if the soil in the southern exposure is dry, while in the northern exposure it is wetter.)

4. The CO_2 concentration in the 20 cm soil gas is generally higher than at 5 cm. (It will be shown later in connection with this, that it holds only if the upper pedosphere is substantially drier than that lying below it.)

If the main conclusions drawn form point 1 and from points 3 and 4 are compared, it is clear that they undoubtedly contain some contradiction. It the proportion of CO_2 in the soil air is inteed directly related with the thermal level, then it would justly be expected that the CO_2 concentration of the soil gas would be more significant on the slopes of northern exposure receiving a higher insolation calory total, and also at the 5 cm soil level which is heated up more readily. In the given case, however, two circumstances must also be taken into consideration, which mar the biostimulative effect of the thermal level and its true reflection in the carbon dioxide proportion. These are the considerable dryness of the soil on the slopes of southern exposure, and the enhanced aeration of the soil in relation with its dryness.

That the role of the soil moisture on the biological activity of the edaphon (and by extension on the CO_2 production) is not negligible, has already been studied in Figure 4. However, the tremendous importance to be attributed to the degree of aeration of the pore-space of the soil could be decided only from the following daily diagrams taken in the Croatian dolina. The earlier period of still conditions came to an end on the day in question, and the mild gusts of wind exerted a very noticeable effect on the development of the curves (see Figure 9). The essence of these effects can be summarized in the following points.

1. Even a fairly slow wind strongly decreased the CO_2 content of the soil air.

2. This decrease of the CO_2 concentration of the gas is connected not with the slowing-down of the production of CO_2 in the soil, but with the enhancement of the exchange dynamism of the given gas reserve of the pore air space. This can be concluded, for instance, from the large peak at 15 hours for curve II/5, the development of which

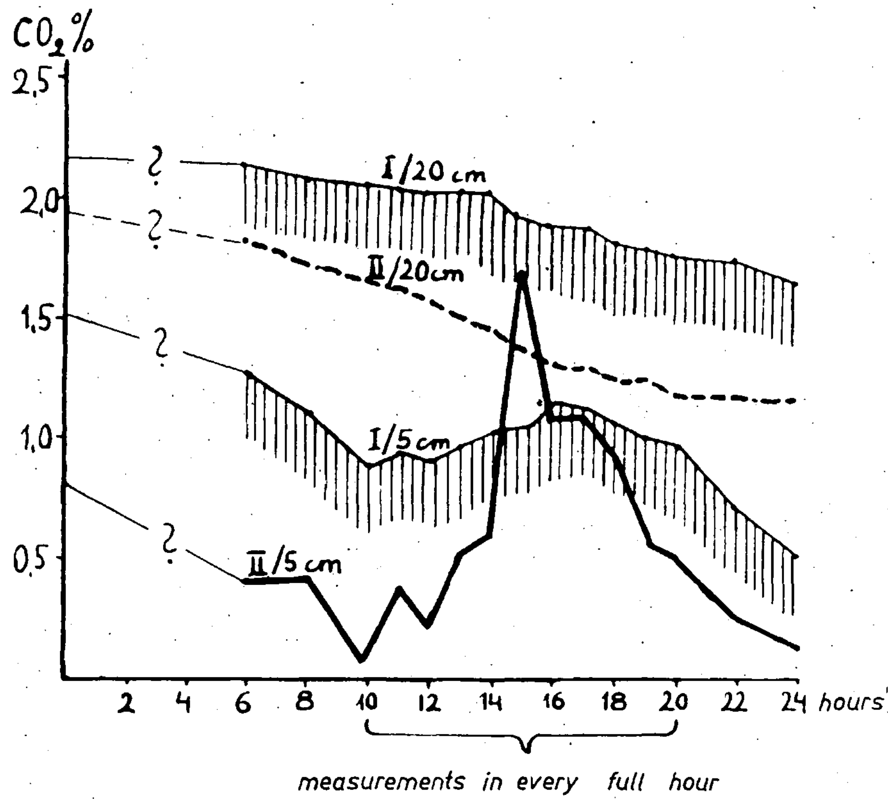


Figure 9. Variations of the CO_2 content of the soil air at the points described in Figure 8, between 6 a.m. and midnight on a summer day (15 July 1968) which was about 60% cloudless, and was moderately windy from the morning hours on (original).

without a transition in the period of calm can be understood only if it is assumed that although the biological activity of the edaphon is successively increased from low values during the earlier hours, the conditions for the remaining of the gas-phase metabolism products in loco nascendi have only now become realized. It must also be assumed that the aerobic processes in the soil are affected favourably by the passage of air through it due to the wind, and thus only the postulates of the accumulation of gas can not be satisfied as a result of the gusts of wind.

3. The wetter the soil, the slower the gas-exchange due to the wind and the less effective the process. This can be seen particularly well on comparison of curves II/5 and I/5. These differences in value, however, again lead to the result only that in both layers studied the CO_2 content of the soil air of the northern exposures still exhibits a higher concentration average than that for the southern exposures.

4. The relatively significant, but brief rise of the CO_2 concentration in the uppermost soil layer has practically no effect on the development of the concentration at lower levels, which decreases slowly during a wide time interval.

The extension of this series of investigations into the third day was justified by appreciable rainfall in the small hours of the 16th. The CO_2 content of the soil air during and following the raining exhibited extremely interesting courses at depths of both 5 and 20 cm. The series of data obtained can be compared from the curves in Figure 10, from which the following consequences are fairly obvious.

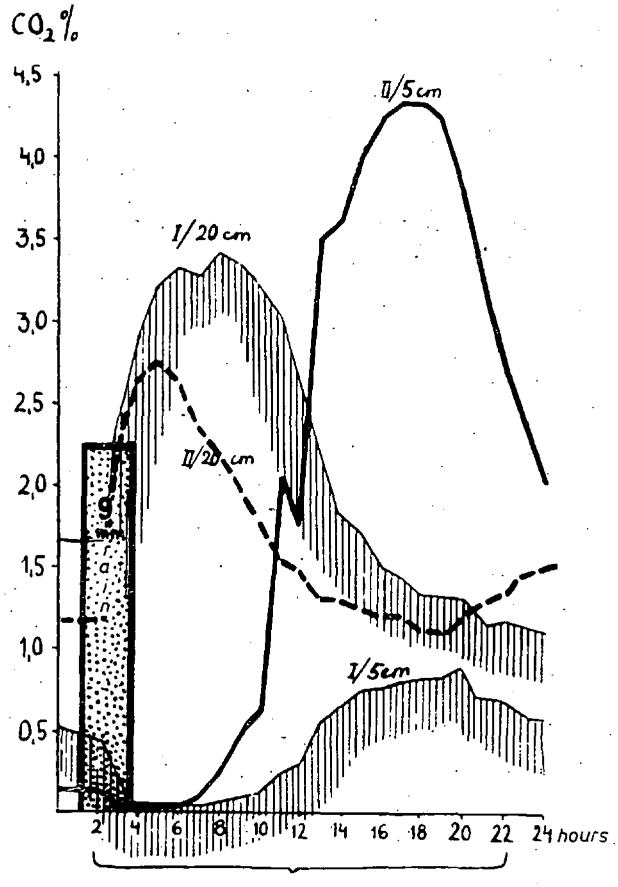


Figure 10. Variations of the CO_2 content of the soil air at the points described in Figure 8, on a cloudless, still summer day (16 July 1968) following a night storm producing about 9 mm rain. The rain, which fell from 1.10 a.m. until 3.35 a.m., was intense in the initial phase, and later gave way to a number of gentler waves with lese precipitation (original).

1. In the uppermost zone of the soil, which is wetted directly by the rain percolating downwards (in our case this included the 5 cm soil level in both the southern and the northern exposures), the rain absorbs the carbon dioxide content of the soil air essentially during the time it is trickling down, and the carbon dioxide is practically completely consumed.

2. In the deeper soil levels, which are not directly affected by the infiltration, immediately following the rainfall the proportion of CO_2 in the pore gases begins to increase rapidly, and compared to the earlier values unusually high concentration levels are attained. Here, therefore, a surprising *inversion* comes about in the CO_2 economy of the soil levels at 5 and 20 cm, which then remains essentially unchanged during the later stages of the day (if there is heating-up by strong insolation during the day).

As regards the cause of the striking phenomenon in the night, we can only think that the swelling of the upper soil layer due to the strong infiltration and hence its temporarily becoming impermeable to air prevent the earlier natural aeration of the deeper soil levels, and thus the gaseous products of decomposition and other oxidation metabolic processes taking place there accumulate.

That this factor may indeed be the principal agent behind the phenomenon emerges from the differences in the 20 cm curves for the southern and northern exposures. The sealing-in of the air due to the wetting comes to an end sooner (at around 5 a.m.) in the soil of the southern exposure (curve II/20), which was the drier before the rain, than in the soil of the northern exposure (curve I/20), which was originally wetter and thus remained soaked with water for a longer period, the concentration of CO_2 in the gas here beginning to decrease essentially only after 8 a.m.

3. As a result of the direct insolation and air-conductance heating-up during the day, the CO_2 production of the 5 cm level in the southern exposure (curve II/5) attains a value significantly exceeding all earlier ones; in this case this is connected with the coincidence of the optimum quantities of heat and moisture developing in the soil during the course of the day. It now appears, however, that the maximum of the peak is obtained with a delay of several hours compared with the usual time for the occurrence of the peak on curve II/5 for the earlier days. This is almost certainly related to the heat-extraction due to the stronger evaporation in the morning.

It should be noted that the counter-tendency of the curve between 10 and 11 a.m. can not be explained, but it is not impossible that it is the effect of a slight air-movement which we did not detect.

4. The fall of the CO_2 concentrations of the 20 cm soil levels during the day, particularly in those periods when this coincides with the increase in the CO_2 concentration of the layers lying nearer to the surface, is difficult to explain. The possibility can not be excluded, however, that

a part is played here by the absorptioon of the soil moisture which has infiltrated meanwhile to a deeper level.

5. The increase in the values of the II/20 curve after 7 p.m. show the effects of the high CO_2 concentration of the gas at a depth of 5 cm.

6. The very considerable differences in order of the afternoon increases of curves II/5 and I/5 indicate that under uniformly favourable soil moisture conditions the CO_2 production of the soil on the southern slopes, which are heated more intensely, will be several times that on the northern exposures. (This latter finding should be compared with point 3 relating to the discussion of Figure 8.)

7. Under favourable soil moisture conditions, primarily in the southern exposures, the CO_2 concentrations of the uppermost soil levels can attain higher values than in the deeper depospheres at these same points.

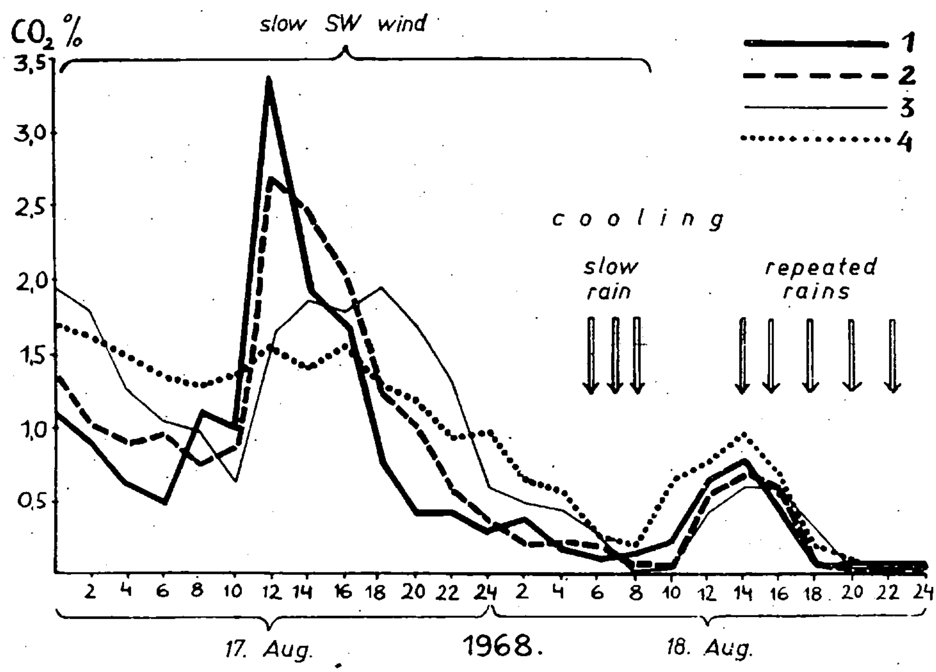


Figure 11. Example of the significance of the exposure on the intensity of karst-formation. Variations of the CO_2 content of the soil gases of the rhizospheres of Festucae growing on the sides of approximately equal steepness, but different exposures, in a dolina at Létrástető (unwooded) in the Bükk mountains, on a hot, sunny day, and the following rainy, cooler day. The curves comparing the results of analysis of the gas samples taken from the root clumps were prepared with measurements at 2-hourly intervals on 17—18 August 1968 (original).

1. Eastern exposure, Festuca sulcata
2. Southern exposure, Festuca sulcata
3. Western exposure, Festuca sulcata
4. Northern exposure, Festuca ovina

(This finding should be compared with point 4 relating to the discussion of Figure 8.)

From the several-day data series recorded on karstic plateaus in *Hungary,* we shall pick out our observations on 17—18 August 1968 in one of the unwooded dolinas at Létrástető in the Bükk mountains. These permit the comparison of the CO_2-economy characteristics of the soil gases of the slopes of northern and southern, and also eastern and western exposures, on a moderately windy, but sunny, hot day, and on the following rainy, cooler day (Figure 11).

In order that the tendencies of the soil gas resulting from the various exposures should be affected as little as possible by disturbing factors, in every exposition stations were established on sections of slope with the same angle of inclination, and rhizospheres of steppe-grasses (Festuca sulcatae) of the same variety and of the same stage of development were studied. Since well-developed Festuca sulcata was not found on the northern exposure, here it was established in the rhizosphere of a Festuca ovina, with somewhat fewer roots. At all points the samples of soil gas were collected from the 5 cm level. It must be noted that in the selection of the dolina an effort was made to site the stations in all exposures at points where the thicknesses and the natures of the soil were practically the same.

The following conclusions can be made from the 2-day series of observations.

1. On 17 August the SW wind (with an average wind strength of 4 according to the measurements of WAGNER at Kurtabérc) had the least disturbing effect on the course of the daily CO_2 level of the soil of the slope of eastern exposure, which was essentially sheltered from the wind. At noon here a CO_2 content of 3.35% was measured (daily peak), which is a very high value in a windy period, and in addition to the morning irradiation optimum is related with the favourable state of moistness of the soil. The peak in the CO_2 concentration curve for the southern slope, and even more so for the western exposure, was appreciably lower, even though the irradiation effects were favourable throughout the entire day. The effect of the dynamic aeration of the soil in decreasing the daily maximum was most strongly exerted on the western slope.

2. It can be seen that there is a difference of about 6 hours between the maxima of the curves for the soils of eastern and western exposures on the first day of the study. A shift of such an extent can be a result only of the differences in heating-up by dirrect irradiation. (On the following day, which was overcast throughout, the maxima on the curves for the various slopes practically coincide.)

3. In the northern exposure, which barely participates in the direct irradiation, the effect of the daily heating-up by air conductance in activating the CO_2 production is almost completely overshadowed by the blowing-out by the wind, and so this curve reflects the tendency of

the CO_2 concentration to decrease, characteristic for a windy day, with an almost uniform fall.

(The fact that the investigation reveals a relatively high CO_2 concentration in every exposure in the early hours of the 17^{th}, is connected with the favourable irradiation and soil moisture values and the calm on the 16^{th}, which on this day presumably led to the development of a very high peak value in every exposure. Unfortunately, in the absence of concrete measurements this assumption can not be confirmed.)

Although it is still not sufficiently clarified analytically as regards the ratio of every effective component, it can already be stated unconditionally that *the CO_2 concentration differences, which express the complex resultant of an extreme number of effects, depend on the exposure.* Those features of the quantities and course of the daily production of the gas, the existence of which has already been demonstrated by our measurements to date on dolina soils of eastern and western exposures, may often be of the same magnitude even as the differences of a similar type for the southern and northern exposures.

On a still day which was unclouded throughout, ANDÓ (1959) generally found the western exposures to be hotter on the banks of the river Tisza, and explains this via the heat extraction due to evaporation on the slopes receiving the early morning sunshine. The search for an analogy is undoubtedly justified, but in our view this is only *one* of the objective factors. We have so far not made a finding of such general validity for the CO_2 concentrations of the slopes of dolinas, for we consider that we are still not in possession of a sufficient number of data series permitting a statistical evaluation for days of different irradiation, wind and precipitation conditions. Our results to date do not otherwise

Figure 12. Diagram comparing spring maximum CO_2 concentrations obtained from the rhizospheres of the plant species of various karstic steppe associations, and from the 5—10 cm layers of the soil of different forest types. The measurements were made on cloud-free, still days in April—May 1967 and 1968 in the Bükk mountains and on the Északborsodi karst (original).
Origin of the soil air samples:

I = from under a wetly coherent cover of dead leaves, second-year, several cm thick, in an oak wood

II = from under a wetly coherent cover of dead leaves, second-year, several cm thick, in a beech wood

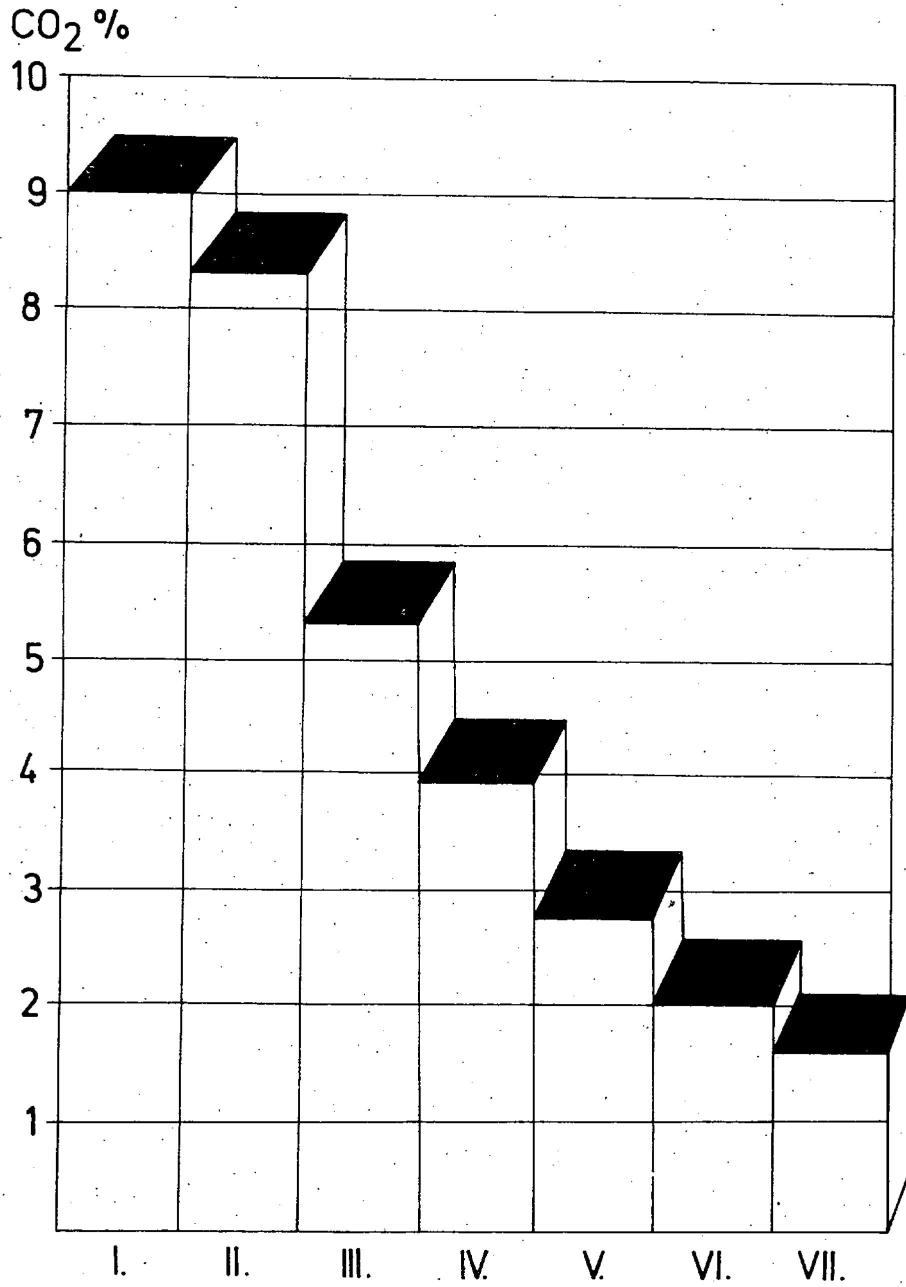
III = from under a carpet of decomposing needles in a pine wood, from a depth of ca. 8 cm

IV = from the rhizosphere of Nardus stricta, from the acidic and deep-soiled bottom of a dolina on the Bükk plateau

V = from the rhizosphere of Festuca sulcata, from the steppe meadow of a rock-strewn dolina slope of south-eastern exposure at Aggtelek

VI = from the rhizosphere of Festuca ovina, from the steppe meadow of a rock-strewn dolina of northern exposure at Aggtelek

VII = from a soil depth of 5 cm under Carex humilis, from the steppe meadow of a dolina side of south-eastern exposure at Aggtelek


CO2 %
10
9
8
7
6
5
4
3
2
1
I.
II.
III.
IV.
V.
VI.
VII.

support a categoric standpoint, since there were cases among the measurements not detailed here when the higher daily CO_2 production was exhibited by the western exposures, but also cases when it was exhibited by the eastern exposures. (This question should be compared with the results of the detailed examinations into the course of the temperature and the soil moisture of the dolina exposures.)

Since the CO_2 production of the soil and the overall CO_2 level are decisive factors of the aggressivity of the precipitation waters infiltraing in the soil, and hence, via this, are the main determinants of the degree of local dynamism of the karst-formation, it can be taken as practically certain that, for example, *the asymmetry of the dolinas* is connected causally primarily not with the petrological, layer-structural (strike and slope orientation) reasons assumed by the CHOLNOKY's, but with the micro-area factors outlined here. Only in this way can it happen that as regards entire mountains the direction of the deformation axis agrees for dolinas formed in limestone layers of different spatial position, as shown by our measurements in this direction in the Bükk mountains, on the Északborsodi karst, in the Mecsek mountains, and on a number of Croatian karst-planinas.

Otherwise, the various plant individuals and association-types certainly have species-specific properties in the stimulation of CO_2 production in the soil, and in the determination of the extent of soil aeration, as regards karstic plant-associations too. This becomes particularly striking when a comparison is made between the forest soil gases and those of the steppe-meadows, in so far as the concentration of CO_2 in the soil of forests is almost always substantially higher than that of the soil of meadows with no forest flora. There are several reasons for this difference. We consider the following to be the most important of these.

1. The moisture level of forest soil exhibits lower extremes, and is essentially more favourable than that of steppe meadows.
2. Because of the foliage, the forest soil is protected from the wind.
3. The forest soil is generally covered by a horizontally layered, unbroken mass of dead leaves, etc., the effect of which in inhibiting aeration may be appreciable.
4. The extensive and deep-acting rhizosphere of the trees significantly increases the depth of the bioactive soil zone, which is most important from the aspect of subcutaneous CO_2 production, and via this also increases the edaphon number relating to unit surface.

Figure 12 shows some characteristic data from our observations, on the basis of which the above points were formulated. It can be seen that as regards the karst process the most favourable soil gas conditions on Hungarian karsts are to be found under oak and beech associations, and the gas production of the soil of karst bush-forests, and particularly of steppe meadows, is less than that in the above forests. The CO_2 content of the soil of pine forests even is higher than that for steppe vegetation.

Interestingly, the maximum CO_2 concentrations in the rhizospheres of grassy plants were found for Nardus stricta, which prefers moisture and coolness. We can explain this only as a varietal characteristic, since the soil moisture features were also optimum for the root levels of Festucae and Carexes studied in exposures substantially more favourable as regards the heating-up during the period of the researches.

It will be mentioned here that the valuable results reported by BALÁZS (1964) in connection with consistent correlations between the compositions of karst springs of the temperate zone and the vegetation conditions of the related catchment areas, also confirm the higher CO_2 concentrations of soils of forest vegetations, and hence underline the significance of the effect of the nature of the vegetation on the dynamics of karst-formation (Figure 13).

In the decision of the question, naturally, one should not overlook the fauna of the soil either, since the animals living in the soil certainly contribute to the change of composition of the soil gases with their metabolism. However, studies have not yet been made to determine the magnitude of this effect and its assertion in karst corrosion.

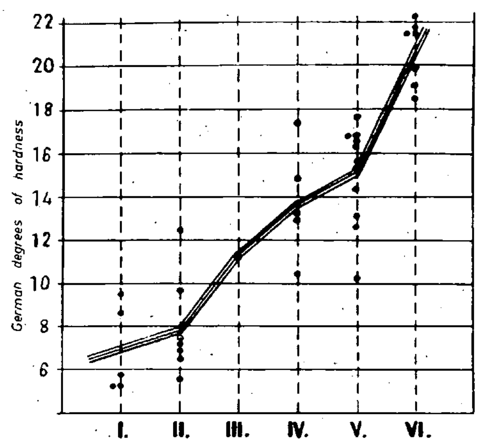


Figure 13. Relation of the water hardness of temperate zone karst springs with the vegetation cover and vegetation types of the revelant karstic catchment areas. The Roman numbers indicate the following groups:

Group	Distribution of catchment areas			Average hardness of studied water samples
	forest %	meadow, pasture, bush-forest %	rocky, bare %	
I	—	0—10	80—100	7,0 Gh°
II	—	30—60	40—70	7,8 Gh°
III	max. 10	60—90	10—40	11,2 Gh°
IV	0—25	75—100	max. 10	13,7 Gh°
V	20—75	25—75	max. 10	13,0 Gh°
VI	75—100	0—25	max. 10	20,7 Gh°

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THEORETICAL AND METHODICAL PROBLEMS OF RELIEF ENERGY MAPPING

by

DR. J. FEHÉR

Geomorphology gathers useful basic facts through the results of orometric, hypsometric, and relief energy investigations for the definition of the relief form combinations or relief types. Earlier SONKLAR (1873), PARTSCH (1911), KREBS (1922), BRÜNING (1927), BEHRENS (1953), and THAUER (1954) dealt with calculation and mapping of relief energy. In Hungary it was LÁNG who made a relief energy map of the medium high Mátra and Börzsöny (1955) and a relief energy map of Hungary (1962) using and perfecting the method of KREBS, while the author of the present paper dealt with mapping of the relief energy of flat and hilly country (FEHÉR 1971).

KREBS (1922) was amongst the first who tried to use, besides absolute altitude data of the relief, also the magnitude of the relief energy to differentiate the types of relief. According to him we can call a plain an area the relief energy of which is under 200 m. The relief energy of perfect plains does not exceed 30 m and the sloping of their surface is no more than 6‰. In our temperate humid climate the name medium high mountain can be applied only to an area the relief energy of which is less than 1000 m. If it is more than 1000 m, the mountain is termed "high".

KREBS remarks in connection with this that in the categorization of mountains on the basis of altitude the concept of "high mountain" is often confused with the terms "high mountain character" or "alpine relief" which refer to the richness of forms of the mountains. In order to clear this he proposes that in the definition of the categories of medium high and high mountains only absolute altitudes should be considered, i.e. up to 1500 m altitude we should speak of "medium high" mountains, while mountains higher than 1500 m should be termed "high". Again, the term "alpine relief", which characterizes the mountains morphologically, should be used only on the basis of relative differences of altitude, i.e. on the basis of relief energy. According to him the term "alpine relief" should be applied only to mountains with higher than 1000 m relief energy.

It should be noted that KREBS worked on the basis of a 25 km^2 network wich means that the relief energy values mentioned by him always refer to relative altitude differences measured within 5 km distances; in other words the basic unit of the relief energy indexes is 25 m/km^2 in his system.

The relief energy values can no doubt be well used for a more precise, more exact definition of the concept of the different types of relief, but a difficulty arises from the fact that the methods of calculating relief energy are not uniform and they are not in general use. Even in the case of relief energy examinations made on the basis of relative altitude differences calculated within given distances in a squared network the starting point, the size of the network of squares or meshes is different with every author. PARTSCH for instance worked with a network of 32 km^2, meshes KREBS with a network of 25 km^2, LÁNG with a network of 88 km^2, one of 4 km^2 and one of 1 km^2 meshes; thus they calculated also the differences of altitude within 1 km distances. Consequently the relief energy maps published by the different authors cannot be compared, and the upper limit values (perfect plain 30 m, plain 200 m, medium high mountain relief 1000 m, high mountanin relief above 1000 m) proposed by KREBS for definition of the types of relief cannot be applied uniformly because *the use of networks of different mesh sizes gives quite different relief energy values.* This conclusion is illustrated by the following example.

On the map of the Mátra mountain of Hungary made by LÁNG with a network of 1 km^3 meshes the highest relief energy value is 360 m, while on the map with a network of 4 km^2 meshes the relief energy of the same area is 520 m, on the relief energy map of Hungary with an 88 km^2 network the whole area of the Mátra mountain is shown as having higher than 300 m relief energy and the highest parts have values of 800—850 m. It is obvious that on the basis of these relief energy maps with different network sizes no limit values of general validity can be used.

The relief energy examinations made by the author in plain and hilly country and the relief energy maps of medium high mountain areas made by LÁNG and the relief energy maps of the eastern Alps made by KREBS convince us that *the smaller areal units are used for a relief energy map, the more truly does it represent the real aspect of the relief.* A large-size mesh falsifies, especially in the case of the relief of plains, the picture of the vertical arrangement of the surface features. This is shown in Table 1 in which the relief energy values of the same region, the area of the Danube-Tisza interfluve, are compared on the basis of relief energy maps made with a 1 km^2 network by the author and maps made with an 88 km^2 network by LÁNG in relation to the area and in percentile distribution.

In this perfect plain in the alluvial flood basin of the rivers the value of the relief energy is generally 0—4 m/km^2. There is hardly a perceptible eminence here; rather it is the remains of filled-up one-time river channels that lie a little lower than the average level of the land. In spite of this the relief energy map with a large meshed network shows high values here too which are not characteristic of the real landscape. This error is due to the method. If for instance a solitary eroded inselberg rises 20 m above quite level land, then only those squares show such a value in whose area the eminence is. In the case of a large-

TABLE 1

Relief energy	1 km² network		88 km² network	
	Area in km² and %		Area in km² and %	
o—10 m	12297	97,4 %	3344	26,4 %
10,1—15 m	224	1,8 %	2640	20,8 %
15,1—20 m	74	0,6 %	3168	25,0 %
20 m	21	0,2 %	3520	27,8 %
Total	12616	100,0 %	12672	100,0 %

meshed network, however, the whole square of 88 km^2 is given the value of a hill of only a few square kilometers even though all the rest of the area is perfectly flat and without differentiated surface features. This why the two columns of Table 1 present quite different pictures: cn the basis of the goss-meshed netwok 73,6% of the whole area has a relief energy of 10—30 m and only one quarter of it has a value of 0—10 m. In contrast to this on the map with 1 km^2 mesh network 97,4% of the area has a relief energy of less than 10 m (of this 58% = 0—2 m/km^2, 23% = 2—4 m/km^2, 10% = 4—6 m/km^2, etc.) and only 2,6% has a relief energy above 10 m.

Relief energy maps constructed on the basis of relative altitude differences calculated in a network of 1 km^2 meshes and value categories corresponding to the relief properties (degree of vertical differentiation of the surface features, petrological structure etc.) show well the distinct features of the relief but also the structural and morphological properties which are the result of the interaction of endogenous and exogenous factors involved in the formation of genetically different areal units.

This is well illustrated by the parts of the relief energy maps presented which show the distinctive relief energy conditions of different types of relief: perfect plain (Figs. 1, 2, 3), imperfect plain (Fig. 4), hilly country (Fig. 5), and medium high mountains (Fig. 6).

Our method of construction the maps was as follows: On the 1:25 000, scale topographic maps a network with 1 km^2 meshes was laid, and with the help of the altitude data or contour lines the numeric value of the difference of altitude in meters between the lowest point and the highest point was determined and then, as a relief energy value, referred to the center of the square. Points of the same value obtained by interpolation were connected by so-called iso-relief energy lines on the basis of value limits chosen according to the character of the given area. After this the territorial distribution of relief energy was represented by hachures.

In areas of plain-like character where the relief energy is mostly under 10 meters a grading of 2 m from 0 to 10 m (0, 2, 4, 6, 8, 10 m) was used. Upward of 10 m, higher value limits, growing parallelly with

TABLE 2

Percentage distribution of relief energy indexes in different of relief

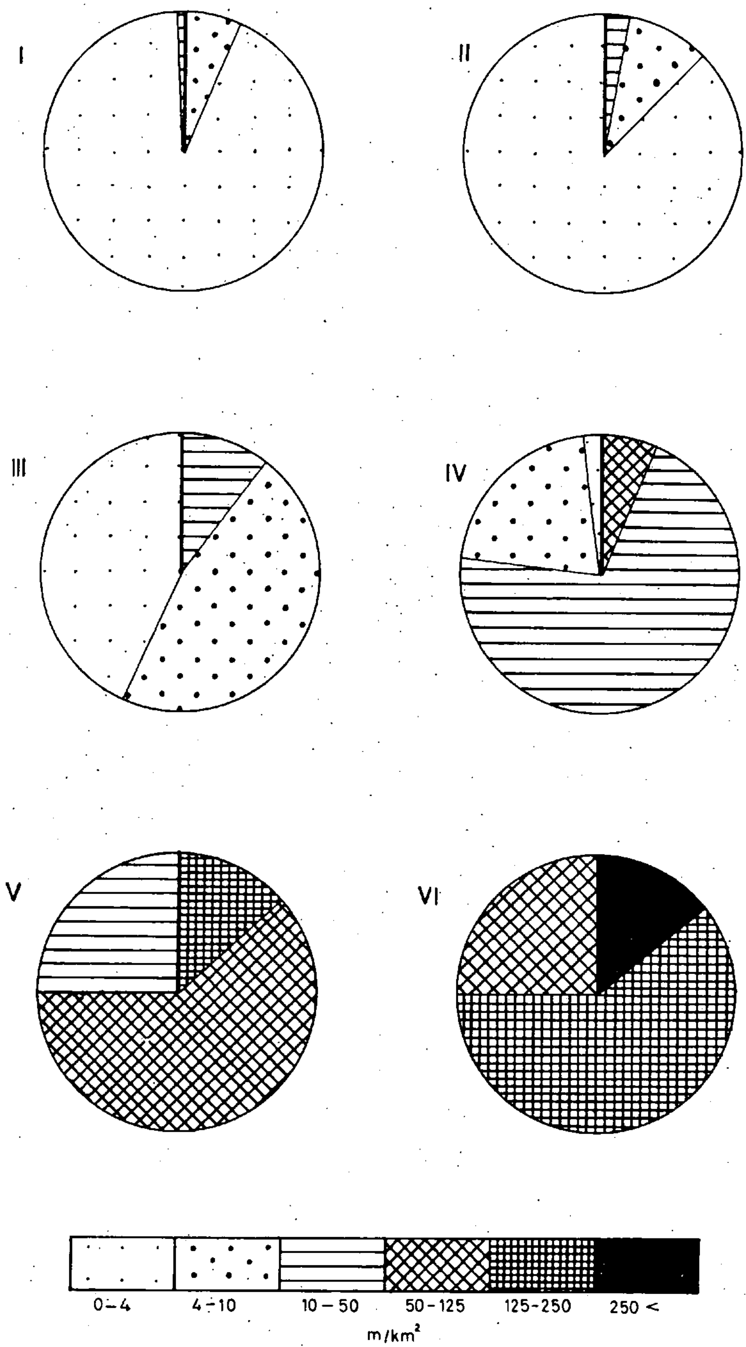
Relief energy m/km²	Perfect plains			Imperfect plain	Hilly country	Medium high mountain	
	fluviatile	eolic	fluviatile and eclic				
	Danube valley plain	Sandy area in Danube Tisza inter-fluve	Loess plain of Bácska	Loess area in Mezőföld	Hilly country of Szekszárd	Börzsöny	Mátra
0— 2	70	77	11	0,5	—	—	—
2— 4	23 } 98 %	11	32	1,5	—	—	—
4— 6	5	4 } 97 %	23 } 90 %	6,0	—	—	—
6— 8	1	3	13	9,0	—	—	—
8— 10	0,3	2,4	11	8,0	—	—	—
10— 20	0,7	2,4	8	33	5	—	—
20— 30		0,2	1,5	22 } 69 %	5	—	—
30— 50			0,5	14	15	—	—
50— 75					20 } 77 %	—	—
75—100					27	10	4
100—125					15	15	20
125—150					11	14 } 76 %	16 } 85 %
150—200					2	26	29
200—250						21	20
250—300						8	8
300 m<						6	3
	100 %	100 %	100 %	100 %	100 %	100 %	100 %

the meters, were chosen. Thus categories between 10, 15, 20, 30, 50 and 75 meters were represented.

For the hilly country and medium high mountain types of relief even wider value limits (50, 75, 100, 125, 150, 200, 250, 300, 350) had to be used on account of the much higher relief energy.

The characteristic relief energy conditions of the different types of relief are tabulated in Table 2 on the basis of statistical analyses of data of relief energy maps. The territorial distribution of the relief energy characteristic of the different types of relief can be seen from the table.

1. The type of areas having the lowest relief energy in the Great Hungarian Plain is represented by the wide alluvial flood plains formed


I
II
III
IV
V
VI
0–4
4–10
10–50
50–125
125–250
250 <
m/km²

by fluviatile accumulation which lie at an altitude of 80—100 m. Their relief energy is extremely low. Two-thirds of their area has a relief energy of 0—2 m, while the relief energy of more than 90% of the whole territory is below 4 km. The relief indexes between 4 and 6 m are negative surface forms: they are imperfectly filled one-time branches and abandoned channels or artificially cut-off ox-bows of the Danube. Hardly can a value above 6 m be found in the whole area. Eminences with 15—20 m relief energy can be found at two spots; they are two small eroded inselbergs that rise like foreign bodies from the perfectly flat alluvial plain near the Danube. Such a low relief energy is a regular characteristic of young potamogenic plains formed by fluvial leveling.

The distribution of relief energy according to chategories is shown in Table 2 which is based on the evaluation of an area of 1200 km² of the plain on the left bank of the Danube. Fig. 1 shows a small part of this area.

2. *The land with drift-sand in the Danube-Tisza interfluve* presents a more varied picture. Here the surface was shaped by the wind. With the help of the relief energy map two types of areas with different morphological appearance can be distinguished: deflationary areas and accumulation areas.

Most of the *deflationary areas* (80—90%) have low relief energy with chiefly negative surface forms. The subsoil water table, which is generally near to the surface, determines the lower limit of the effect of deflation; therefore only shallow deflationary depressions could form, in some of which there are temporary or permanent lakes. In some places relatively 4—6—10 m high, isolated, very gently sloping sand ridges parallel with the prevailing NW wind direction rise above the low relief energy basal terrain. It is first of all these positive surface formations that distinguish these areas in respect of relief energy conditions from the otherwise very similar fluviatile accumulation conditions. (See the eastern part of Map 2.)

Among the deflationary surfaces there are so-called *eolic accumulation areas* with much more varied relief energy. In these eolic areas the relative height of the agglomerated sand dunes reaches even 10—15 m; thus the relief energy exceeds even 20 m/km² in some places. (See the western part of Map 2.) In these areas the ratio of the relief indexes between 4—15 m/km² is higher.

3. *The loessial area of Bácska* is situated in the SW part of the rolling plain of the Danube-Tisza interfluve, and is characterized by higher average relief energy due to the effect of the material of the superficial loessial rock. The relief energy is 2—6 m/km² in 55% and 6—15 m/km² in 32% of the 750 km² area. These are extensive patches made still more varied by small areas with 10—30 m/km² relief energy values which constitute 10% of the whole area. The relief energy of 0—2 m/km² characteristic of the fluviatile and eolic surfaces described in the foregoing constitutes here only 11% of the area (Fig. 3). This character of the relief energy can be attributed to the effect of the

material of the loessial rock, the intense linear carving effect of small streams, and the deflationary action of the wind.

4. The southeastern part of *Mezőföld* represent another type of relief, the *Imperfect plain* which is an area of 1300 km^2. (Fig. 4.) The closer hachures of the map indicate clearly the generally higher relief energy, while the wide range of relief indexes shows the varienty and sharp division of the relief. 69% of the surface has a relief energy of 10—50 m/km^2, and its distribution within this can be said to be fairly even. (33% of the area has a relief energy of 10—20 m, 22% of it 20—30 m, and 14% of it 30—50 m/km^2). There are here already values exceeding 50 m, though they constitute only 6%. On the other hand relief indexes between 0—4 m are characteristic of only 2% of the area.

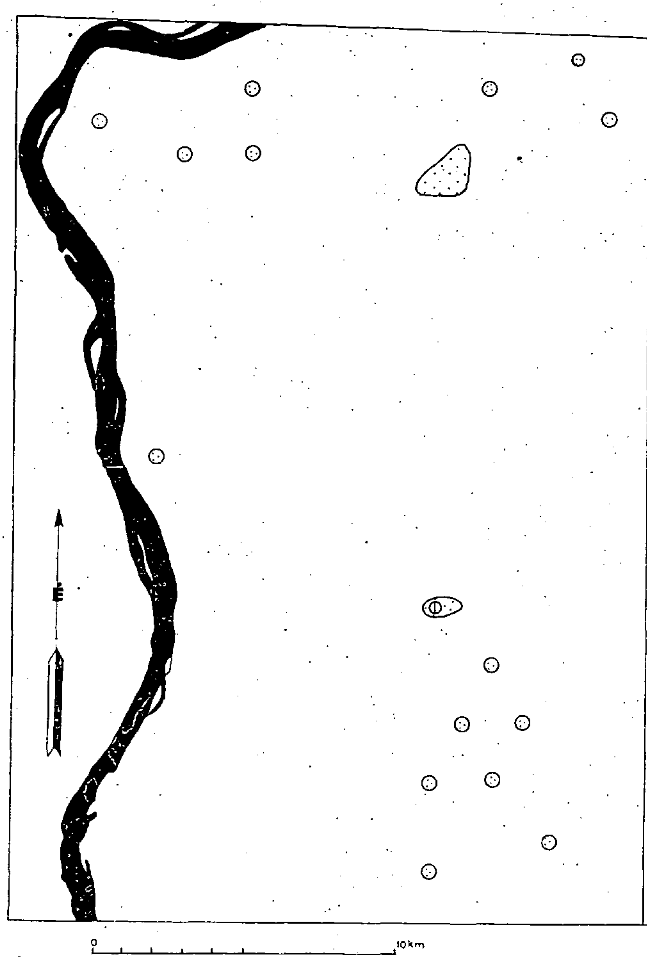


Figure 1. Relief energy map of an alluvial flood plain on the left bank of the Danube.

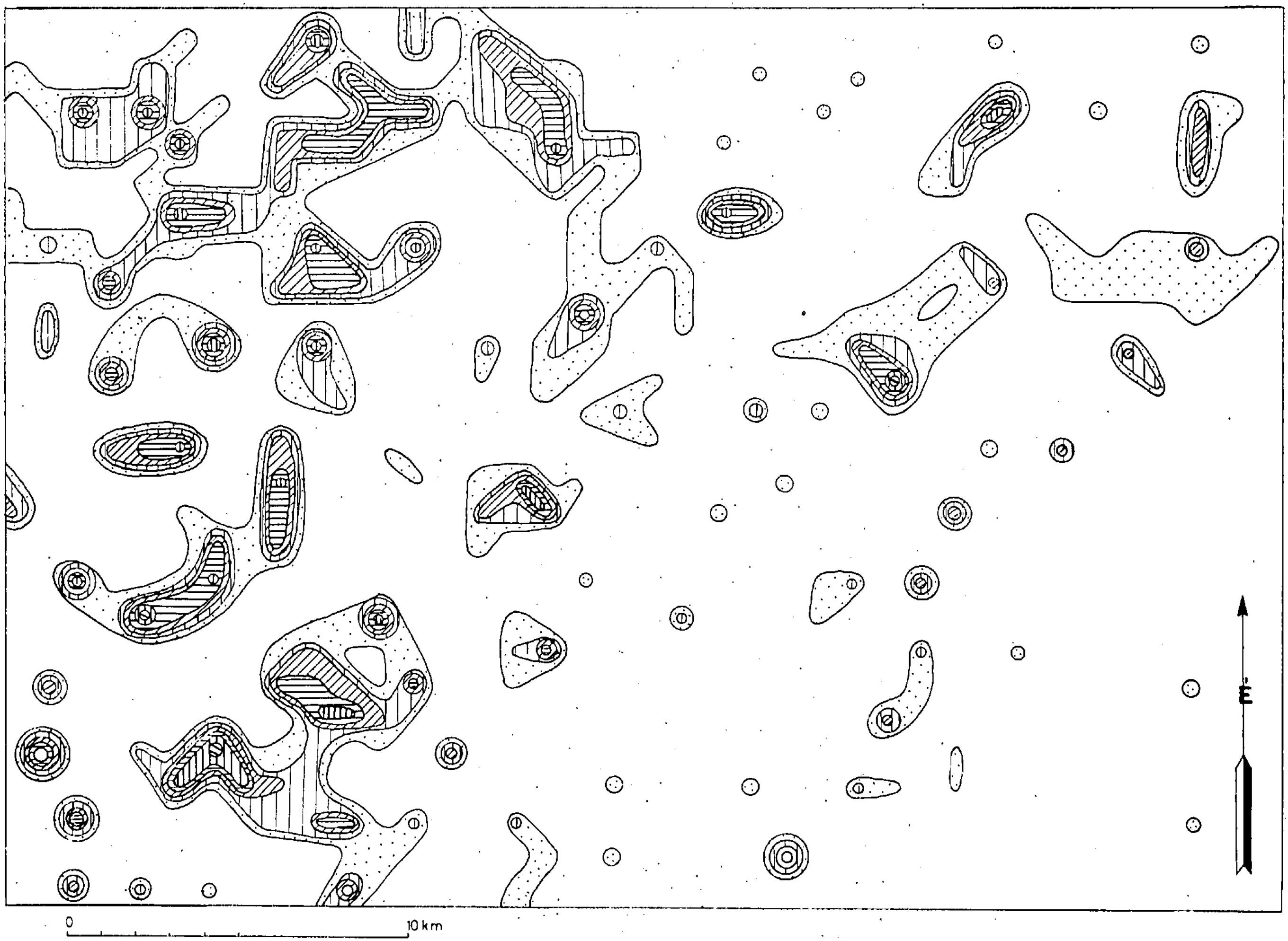


Figure 2. Relief energy map of a land with drift-sand in the Danube-Tisza interfluve

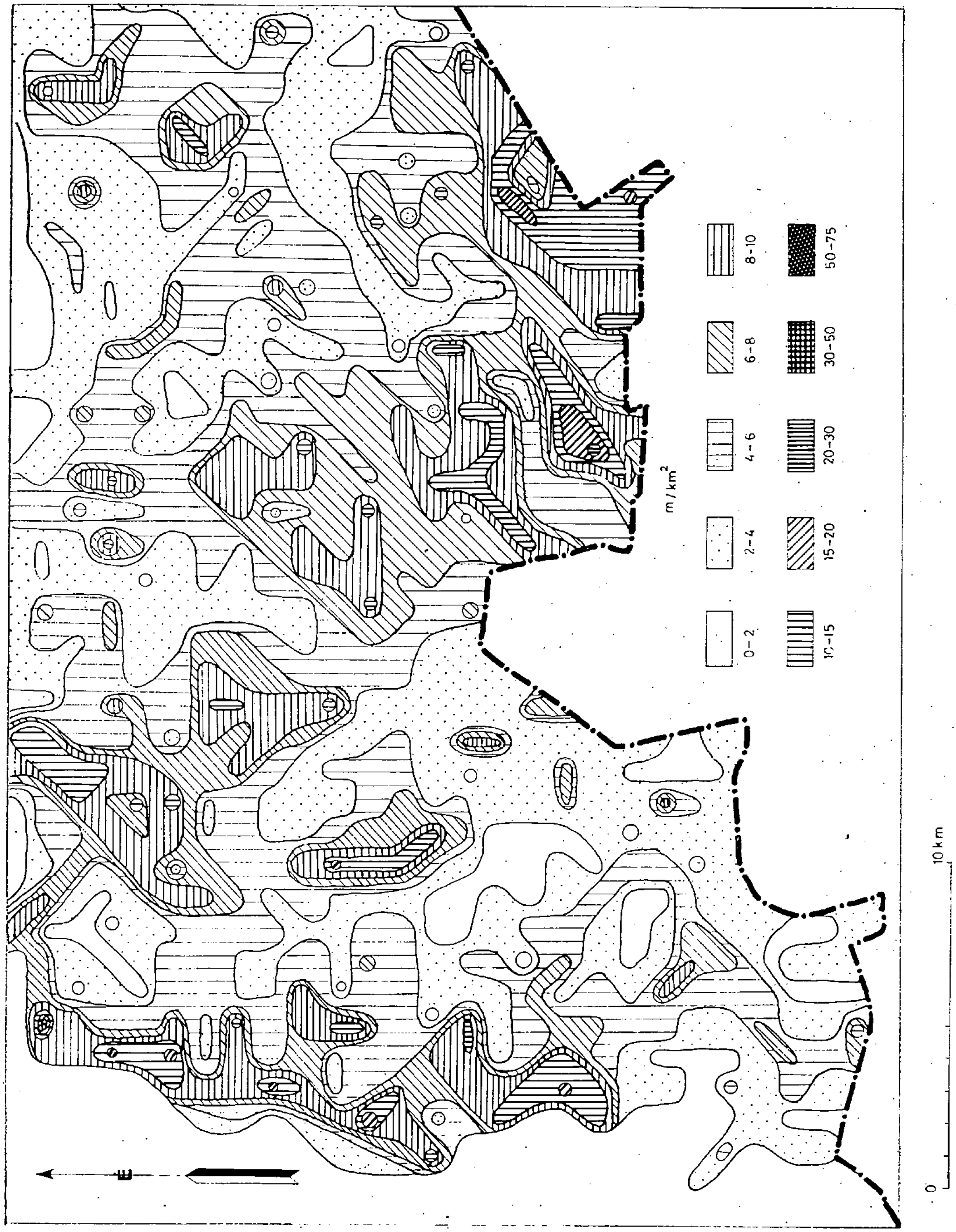


Figure 3. Relief energy map of a loessial area of Bácska.

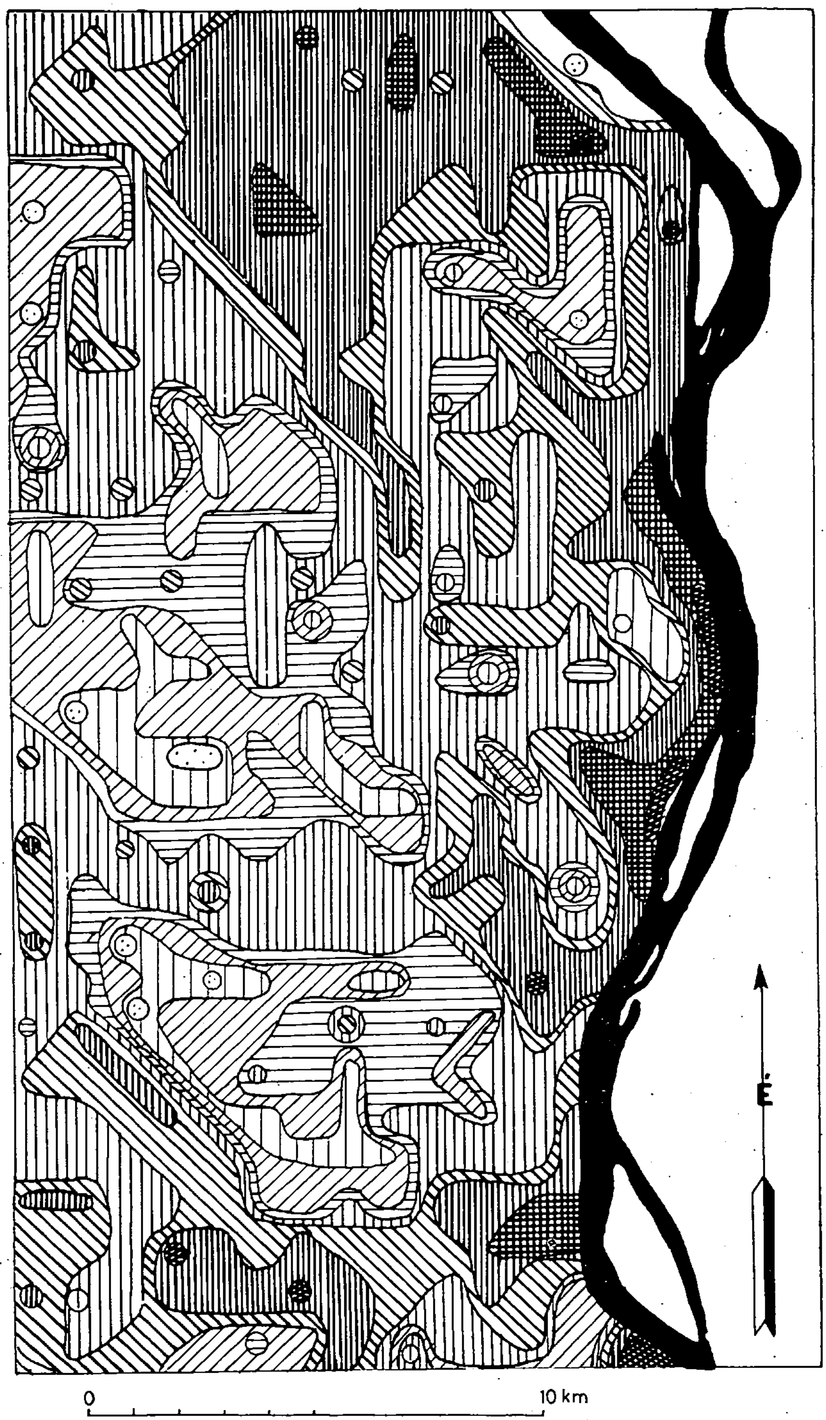


Figure 4. Relief energy map of the southeastern part of Mezőföld.

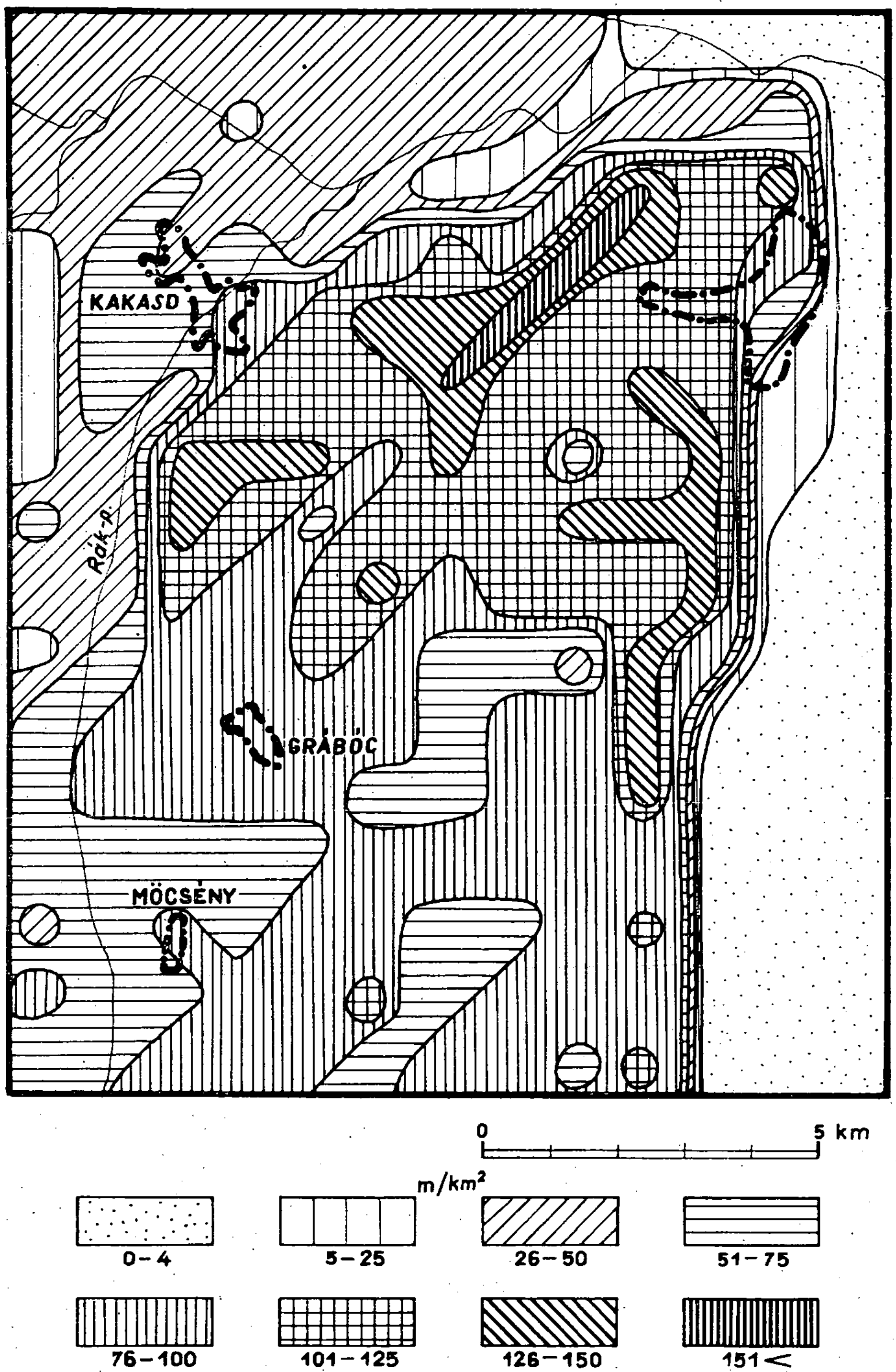


Figure 5. Relief energy map of the hilly area of Szekszárd.

5. The relief energy conditions of *hilly country* are shown in the relief, the *Imperfect plain* which is an area of 1300 km². Fig. 4. The closer sdanubia (Fig. 5). The land surface covered by a 20—40 m thick layer of loess and made up of Pannonic clay, sand, and sand-stone rocks was cut up into irregular pieces and raised to different elevations by tectonic movements in the Pleistocene epoch, while the northern and eastern peripheral parts of the hilly area sank stepwise along parallel faults. The small streams of the area have steep gradient and thus they have contributed with their intense linear erosive action to the division of the terrain. As an example characteristic of the density of the network of valleys the area of Parászta valley may be mentioned the 2,5 km² catchment basin of which is dissected by 14 lateral valleys.

In this hilly area the trend of the patches with identical relief energy values are determined first of all by the structure lines; the magnitude of the relief energy by the absolute elevation of the area (150—300 m altitude above sea-level) or the magnitude of the tectonic movements of the crust. The distribution of the relief energy here is as follows: In 77% of the area values of 30—125 m/km², in 10% of the area indexes of 10—30 m, in 13% of the area more than 125 m/km² are characteristic. Lower than 10 m values of relief energy are not found in the whole area. The largest portion of the area belongs to the 75—100 m/km² category constituting 27%.

6. The *relief type of medium high mountains* is represented by the relief energy map of the Börzsöny mountain (Fig. 6), and the relief energy distribution characteristic of this type of relief is presented on the basis of the evaluation of the Börzsöny and Mátra mountains (see columns 6 and 7 of Table 2). The mountain area to be evaluated was marked off from the area of the foothills along the 100 m/km² iso-relief energy line.

Both mountains were formed approximately at the same time and in the same way. Multiphase neogenic vulcanism was followed by intense erosion; then at the end of the Pliocene epoch uneven elevations along the tectonic faults gave the mountains their present form. The character of uplifted eroded mountains can easily be read from the relief energy map and the steep outlines of the eroded parts, at different heights can be seen from the closeness of the iso-relief energy lines. Owing to similar genetics, rock structure, and absolute altitude. the relief energy shows similar distribution (the highest points being 939 m for the Börzsöny and 1015 m for the Mátra). The largest part of the mountain areas (76—85%), can be found in the relief index range of 100—250 m/km², the categories between 150—250 m/km² being the most heavily represented (47—49%).

Analysis of the relief energy map details and of the distribution of relief energy proves convincingly that the relief energy maps constructed with a network of 1 km³ meshes expose the qualitative differences of the character of the different relief types in necessarily exaggerated form, thereby drawing attention to the factors determining or influenc-

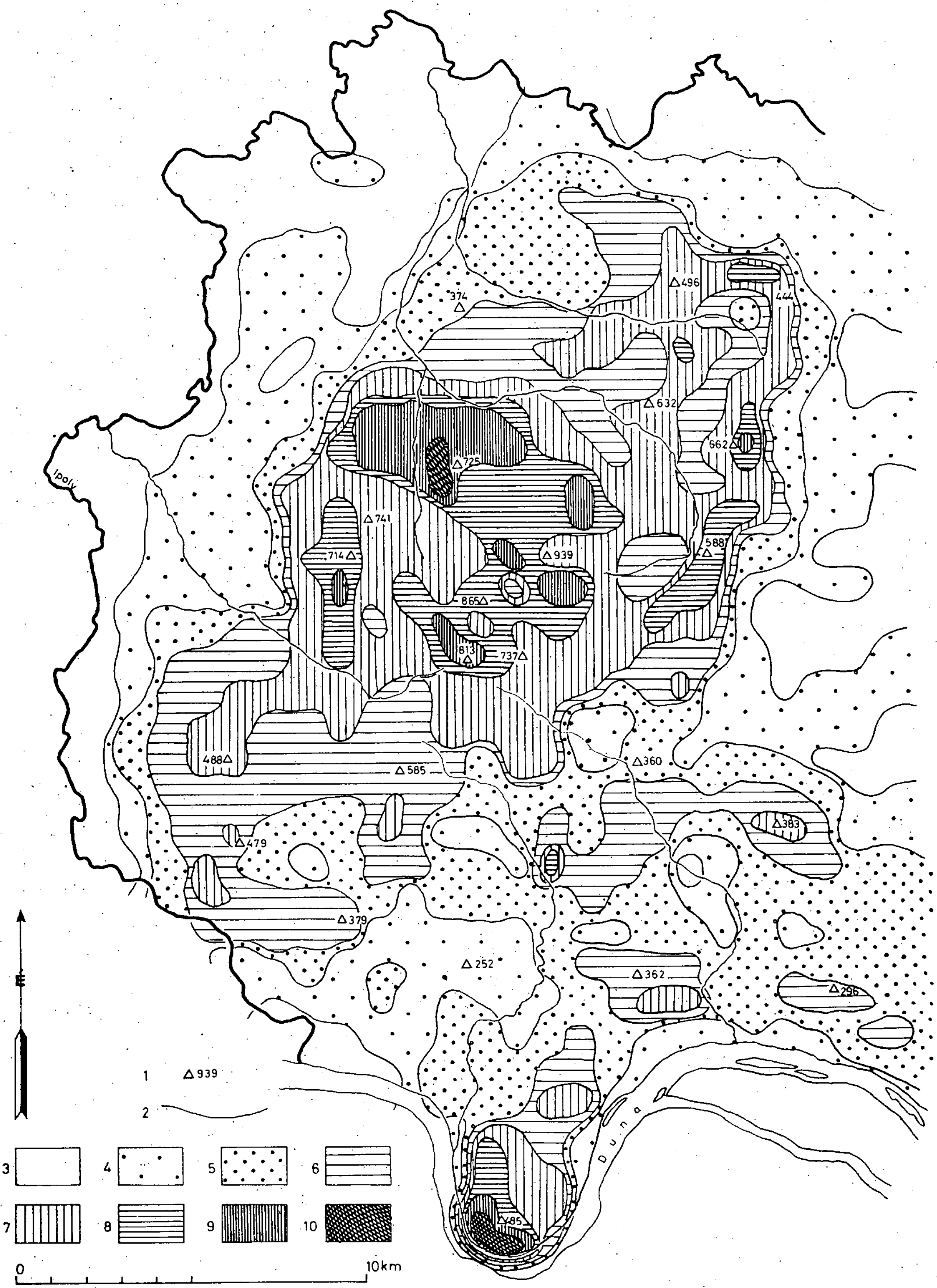


Figure 6. Relief energy map of the Börzsöny mountain (S. Láng 1959.)

ing surface development. The percentage distribution of the relief energy indexes points out also the quantitative differences in the development of the landscape. In this respect the relief energy map provides better information than even detailed hypsometric maps. Therefore analysis and comparison of it with different kinds of special physical geographic maps as well as statistical analysis of the distribution of the relief energy indexes are indispensable for modern dynamic physical geographic landscape evaluation.

On the basis of his experience *the author proposes:*

(1) the general use of maps constructed with a network of 1 km^2 meshes for the purposes of relief energy investigations,

(2) the use of value categories determined on the basis of statistical evaluation of relief indexes referred to 1 km^2 which characterize the different types of relief better. For instance: the term "perfect plain" could be applied to an area 90% of which has less than 10 m/km^2 relief energy. The "imperfect plain" would be an area, two-thirds of which has 10—50 m/km^2 relief energy. The hilly country would be an area, two-thirds of which has 30—125 m/km^2 relief energy, and the medium highmountain an area, two-thirds of which at least has 100—250 m/km^2 relief energy.

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DEFINITION OF THE ECONOMIC MICROAREAS OF THE SOUTHERN PART OF THE GREAT HUNGARIAN PLAIN

by

DR. GY. KRAJKÓ

The definition of the economic microareas of the Southern Part of the Great Hungarian Plain (henceforth Southern Plain) comprises three elements:

a) clarification of the matter of principles of the microareas,
b) carrying out researches of economic space structure,
c) delineation of the microareas.

The three elements are closely connected with each other, as without clarification of the principles it is impossible to investigate the areas and conversely, the experience gained and the analysis of the concrete data enrich the theory. Without doubt it is necessary to investigate the spatial structure of the economy if we are to understand the economic and social processes that are going on within the microareas and which actually determine the character of the areas and lend practical improtance to the drawing of the boundaries. Furthermore, this analysis provides the basis for defining the areas and thus cannot be avoided. Actual definition of the areas can be made after investigation of the spatial structures.

Thus the method used in this investigation not only serves to define the boundaries of the economic areas but also facilitates the investigation of a given area from the economic geographic point of view. It is obvious that an area can be defined only when we know it thoroughly. These obvicus facts must be stated because it follows from them that *the methodological problem of the definition* of the areas is necessarily connected with *the method designed to investigate a given area* from the point of view of economic geography even if they appear to be two different things.

In the investigation of the economic microareas of the Southern Plain the above method was used and the following items were dealt with:

1. *Questions of principle.* As investigations of this kind had not been made in this country, these questions of principle were summarized and an answer to the problems was sought. (Acta Geographica, Tomus XII. Szeged, 1972.)
2. *Economic space structure.* The researches concerned only those branches of economy that are absolutely necessary for the definition of the areas: industry, agriculture, transportation, mobility of population, and the spheres of influence of the settlements.

3. *Definition and outlining of the areas,* which is the third stage of work. The method used in the investigations and the results will be dealt with in the following.

1. The method of definition of the microsareas

The economic areas, which are the territorial units of the social division of labor can obviously be defined also territorially on the basis of the factors that are closely connected with the social division of labor or are manifestations of it. Thus the problem, though simple in principle, is complex in practice.

The practical difficulties are the following:

a) The so-called area-forming factors belong to different spheres of social production and distribution and represent different qualities; therefore their combination encounters unsurmountable difficulties. In addition, the economic area is not only a producing but also a consuming unit. This, too, has indicators that help define the boundaries of the areas. Thus an almost infinite series of factors must be considered for the definition of the areas, but it is impossible to consider all the factors because they do not coincide even territorially.

b) The area-forming factors do not contribute equally to the formation of the areas, e.g. industrial production and agricultural production play a different róle from that of medical and cultural services but the sphere of influence of this role may vary from place to place. The effectiveness of the area-forming processes however, depends to a great extent on the local conditions. For instance the development of agriculture in one place accelerates, and in another slows down, the reorganization of the agricultural population.

c) The role of the factors influencing the area boundaries may differ also depending on the texonomic levels. It occurs that a factor is very important for the microarea, but on the higher levels loses its practical importance. The reverse is also found, e.g. the historical past and the types of the settlements may be important in the definition of the mesoareas, but on the level of microareas it is practically superfluous to include them among the factors. An example of the reverse is the smaller areal units (Göcsej, Sárrét, etc.) with a historically developed common folklore; they are very important at the micro level, but lose their importance on the higher levels.

d) The most important feature of the economic areas is specialization. Among the branches of economy, industry is connected with particular settlements and does not at all mark the boundaries of the areas. The same is often true of agriculture, which is territorially differentiated enough, but the boundaries of the economic area do not always coincide with the integrant area boundaries, which therefore often separate identical types of production. This is understandable since the major commercial and industrial centers have often developed on the borders of different types of agriculture as in the case of Szeged. This proves that these two basic branches of economy, which can constitute the specialization of a particular area, especially in the case of the microareas, often do not coincide.

After the enumeration of so many difficulties it would seem that exact definition of the areas is impossible. This is not at all the case. The aim of pointing out the difficulties was to underline the importance of searching for practicable solutions. It does not matter that specialization is the most important area-forming factor if it can be reckoned with only within concrete limits. Until these limits are known, the factor of specialization cannot be taken into account for this sort of investigation because it cannot show the boundaries exactly and proves the existence or non-existence of the areas only subsequently.

In the first stage of microarea research all the area-forming factors were treated together. Now, in defining the area boundaries, the area-forming factors will be separated in the first stage of work. To one group belong those factors that are indispensable for research but do not indicate the area boundaries indirectly and can therefore not be used for this purpose. To another group belong factors related to the social division of labor and express the differentiated nature of the latter and thus reflect the area boundaries. Also within the second group a difference is made between zonal and nonzonal factors expressing the boundaries. Such a difference must be made because the roles of the two groups of factors are different.

To the factors showing the zonal territorial differences belong the following: factors reflecting

1. the attraction spheres of the settlements,
2. the situation of the settlements from the point of view of transportation geography,
3. the mobility of the population (between 1960—70),
4. the ratio of commuters
5. the transportation of agricultural products for working up in the factories and supplying the markets.

The number of factors to be considered could be increased, but the before-mentioned are sufficient for our purpose. Dealing with the analysis of the economic structure of the Southern Plain the author has already described the relevant factors in detail. Here only a short outline of the same is given.

1. The cartogram showing the attraction areas of the settlements was made on the basis of telephone calls, the cultural and health service attraction, and the industrial attraction of major industrial centers. Thus the nature and proper category of each settlement as well as the strength of the relations and the size of the centers are expressed by the help of features of the economic, social, and cultural life.

The extent of the zones developing around the centers depends on the intensity of the attraction, size, and function of the centers. The following zones can be distinguished on the basis of the map:

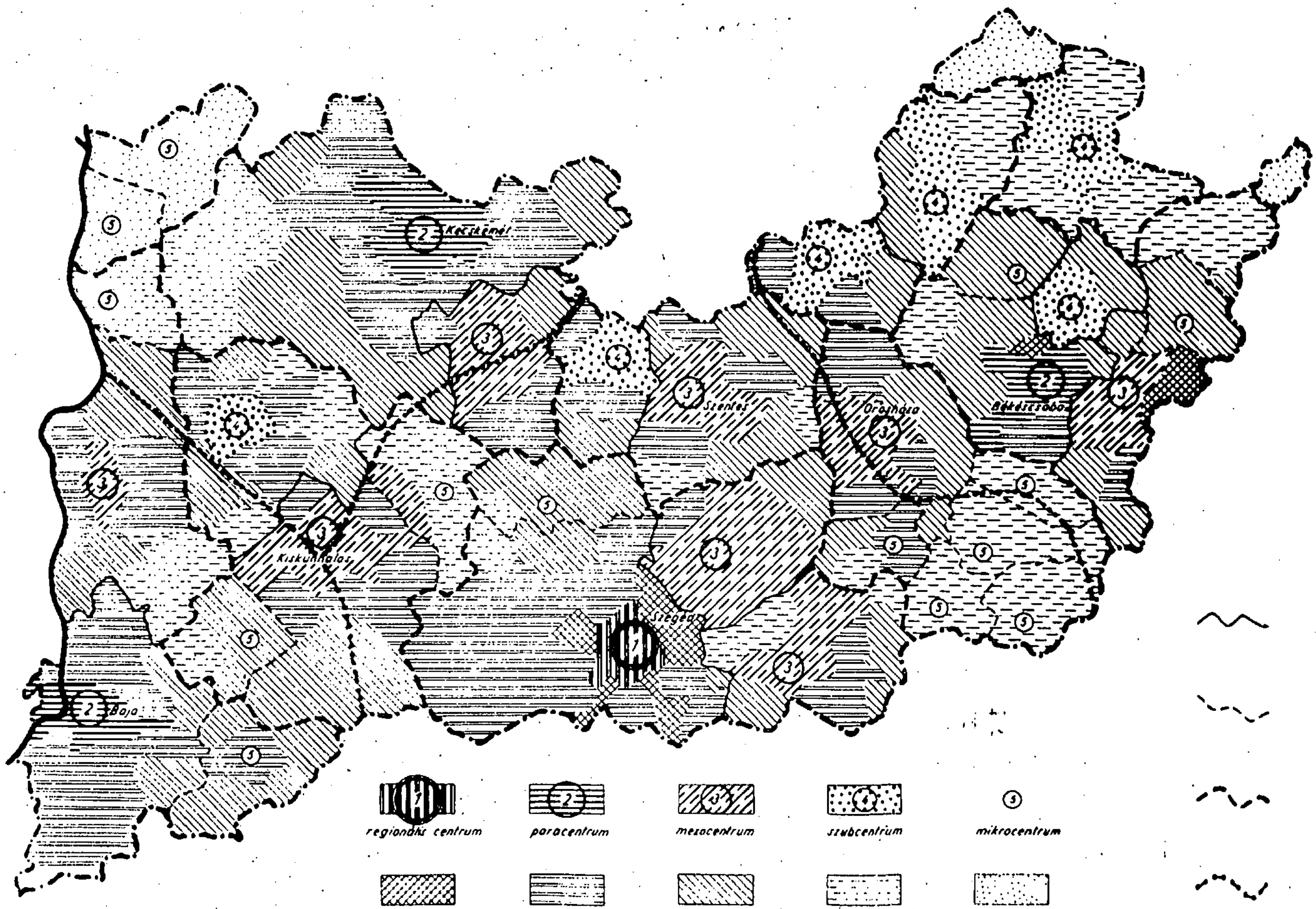


Figure 1. The attraction of centers (Ed. Dr. József Tóth) 1. regional center, 2. paracenter, 3. mesocenter, 4. subcenter 5. microcenter, 6. agglomerating center, 7. hegemonic attraction, 8. dominant attraction, 9. transition zone attracted from several sides, 10. periphery, 11. boundary of attraction sphere (as far as subcenter), 12. boundary of microcenter attraction sphere, 13. boundary of microcenter, 14. higher-grade attraction boundary of paracenters.

- from the point of view of their functions the centers, occasionally together with an agglomeration zone, can be classified in 5 different grades,
- area under hegemonic attraction,
- area under dominant attraction,
- area under multilateral attraction (attraction from several sides)
- area whose category from the point of view of attraction cannot be determined or which does not belong to the Southern Plain as a mesoarea.

In the case of most settlements the attraction spheres show to which center they belong and how strongly they gravitate. For the moment our attention will be given to the latter problem.

2. The transportation geographic situation of the settlements, similarly to the attraction spheres, reflects the situation in relation to the centers, but in this case their categories were determined on the basis of the transportation attraction: As has been described earlier, the map was made on the basis of four factors:

a) the number of bus lines,
b) the ratio of rail or bus commuters,
c) the bulk of freight transport through the settlement,
d) the time needed for reaching the respective centers by the best means of transport.

These factors were then combined mechanically; accordingly, the transportation geographic situation of the settlements is expressed by the formula $\frac{a+b+c}{d}$ in which the letters stand for the factors listed above. Of course in the summing up, where freight and passenger traffic are not considered separately, the ratios are used. Correlation calculations served to check the correctness of the diagram, i.e. how well it reflects the real situation. For example the value of "r" showing the correlation between migration of the population and the transportation geographic situation varies between 0.95—0.44 in the different areas.

On the basic maps showing the transportation geographic situation of the settlements four (in the case of the commuters three) and on the summerizing cartogram 12 categories can be distinguished. As a result of the combination of the basic map with the above-mentioned formula territorial differences similar to the spheres of attraction are revealed.

The transportation geographic situation of the settlement is
- excellent, if its index is above 8,
- good, if its index is between 5—8,
- fair, if its index is between 2—5,
- poor, if its index is lower than 2.

The values obtained in this way show a good agreement with the spheres of attraction.

3. In the case of the mobility of the population the changes in the number of population have been introduced as a factor because during the

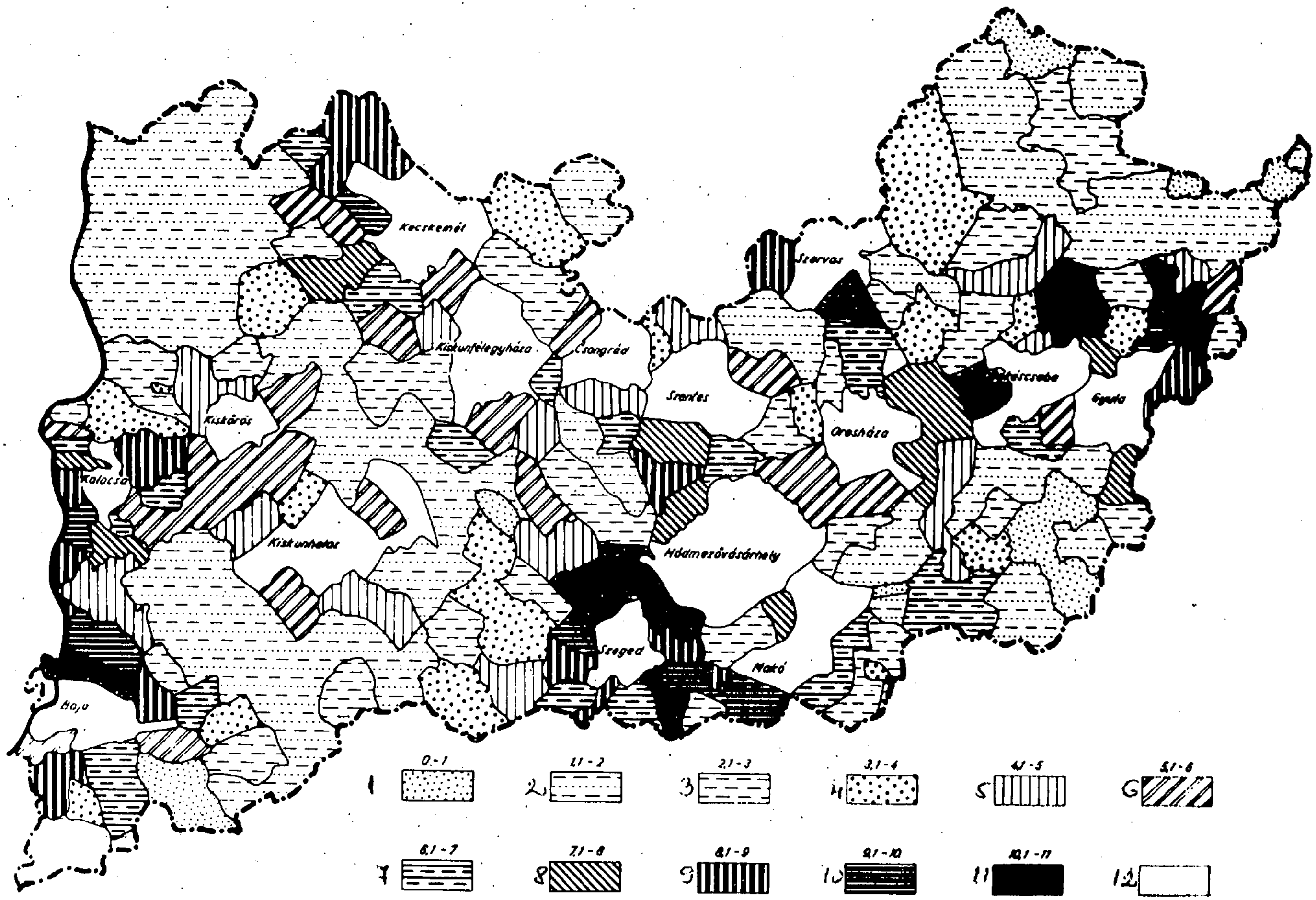


Figure 2. Traffic geography of the settlements of the southern part of the Great Plain.

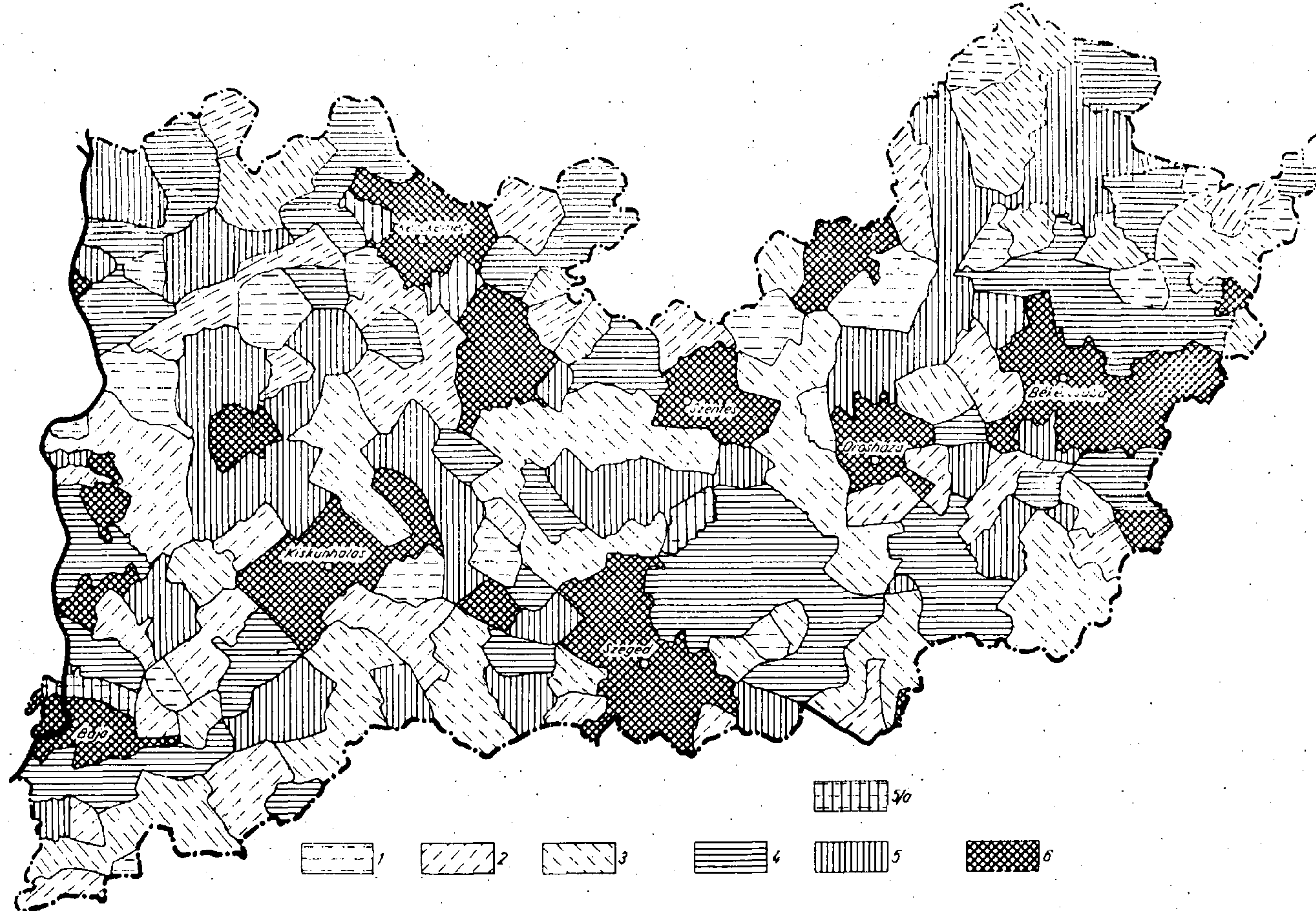


Figure 3. Changes in the population number (1960—1970) and its decrease during the second pentad.
1. the decrease in population was greater than the average, 2. settlements with greater than average population decrease and with weak moderation of the decrease, 3. greater than average decrease but with considerably moderated rate, 4. less than average population loss crease but less than average intensity of decrease over the decade, 5. less than average population loss with intensity of decrease sonsiderably moderated over the decade, 5/a. less than average population loss not moderated over the decade, 6. increased population number.

last decade it has been a reflection of the balance of migration on account of the extremely low natural population growth in the Southern Plain. The extent, direction and fluctuation of the migration are largely due to economic and social causes. Just because of this the centers have had, depending on the degree of industrialization, a great influence on the development of territorial differences.

When the map showing the changes in the number of population is combined with another cartogram showing the intensity of the increase or decrease of the population in the different settlements within a decade. we see interesting territorial differences. The index of intensity can be calculated with the help of the formula

$$I = \frac{\frac{a+b}{2} - b \cdot 100}{c}, \text{ where}$$

I = index of intensity
a = number of population in 1960
b = number of population in 1970
c = number of population in 1965.

As will be seen, many factors are involved in the index of intensity. However we are not going to deal with this here now, because our main concern lies (in the growth of the population of settlements near economic centers and settlements located peripherally, and the difference between them is very great. Furthermore it is very important to know how the rate of growth or decrease changed during the decade so that the territorial differences can be demonstrated in the light of these facts.

The changes in the population number are in agreement with the territorial ratios of migration, the ratio of those engaged in agriculture, and the ratio of commuters. The influence of the transport geographic situation, the intensity of which depends on the size, functions, and distance of the centers is demonstrable and territorially definable in every factor. Similar territorial differentiation and common features of the population indexes make it possible to consider them together. From the point of view of the mobility of the population the settlements can be classified into five categories in which the indexes of the mobility of the population are (1) favorable, (2) relatively favorable, (3) fair, (4) unfavorable, (5) very unfavorable.

4. The results of this present survey of commuters have not yet been published by the Statistical Office and the data collected ten years ago have become obsolete because it is here that industrial development has brought the greatest changes.

We assessed the number of the commuters to several larger towns such as Szeged, Baja, Kalocsa, Kiskunhalas. The results do not modify the area boundaries but rather confirm them. Among other things this is why we did not assess the number of the commuters of the other towns, in itself a not inconsiderable task, and dealt instead with the data of the regular travelers. The directions of travel, however, are not recorded and

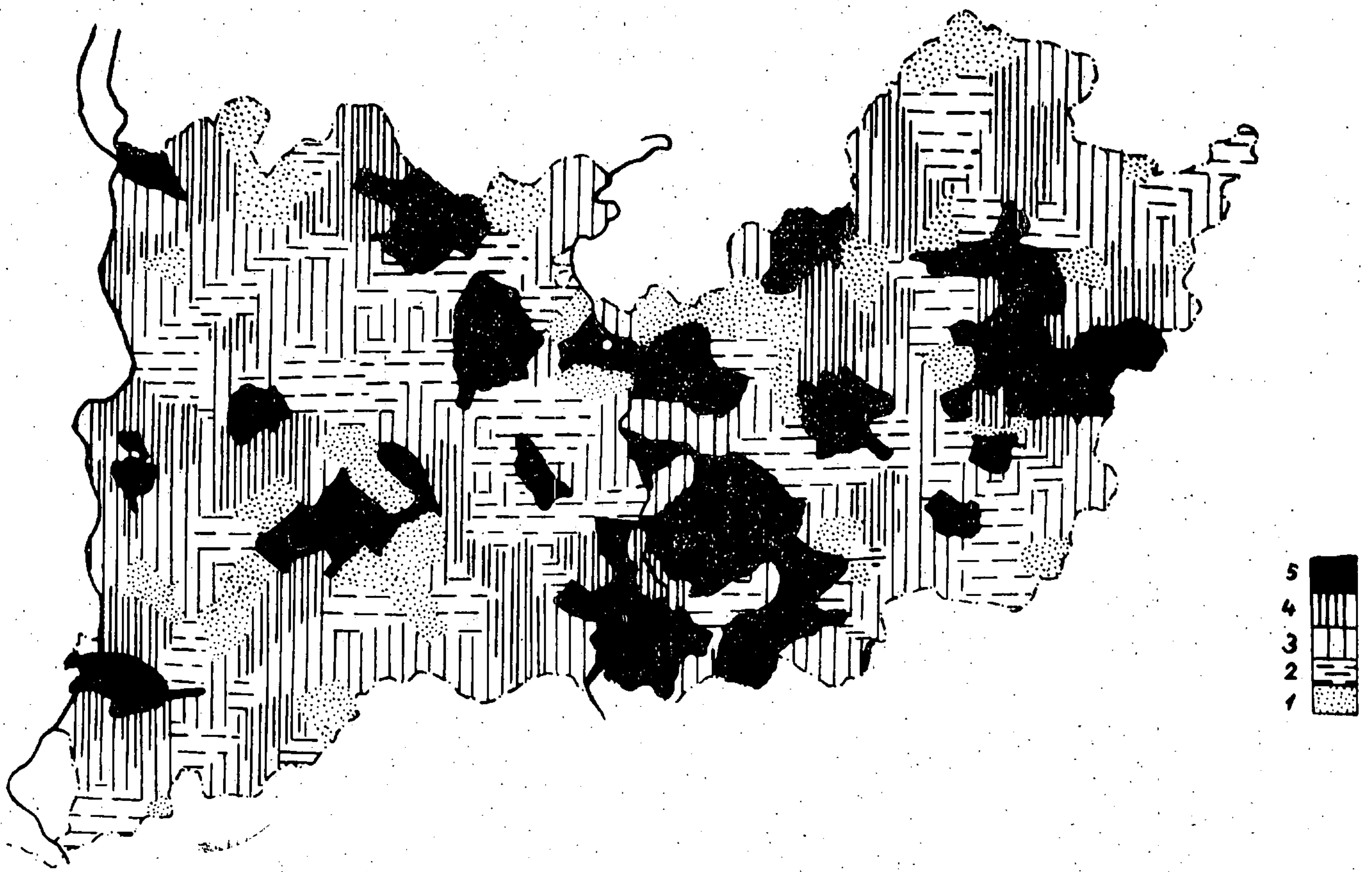


Figure 4. Types of settlements on the basis of the mobility of the population (1960—1970)
1. favorable, 2. relatively favorable, 3. middling, 4. unfavorable, 5. very unfavorable

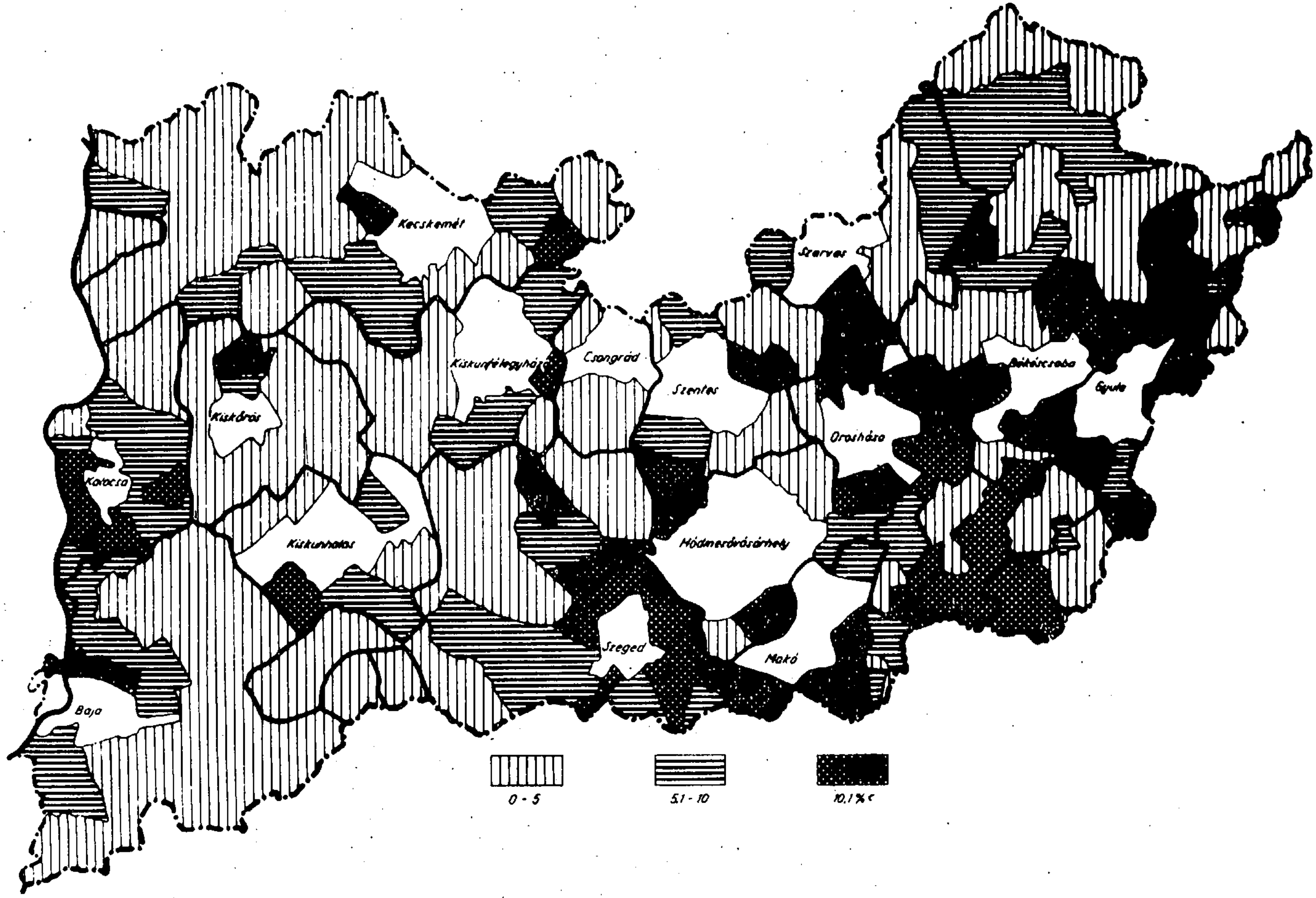


Figure 5. The ratio of the regularly traveling population in various settlements.

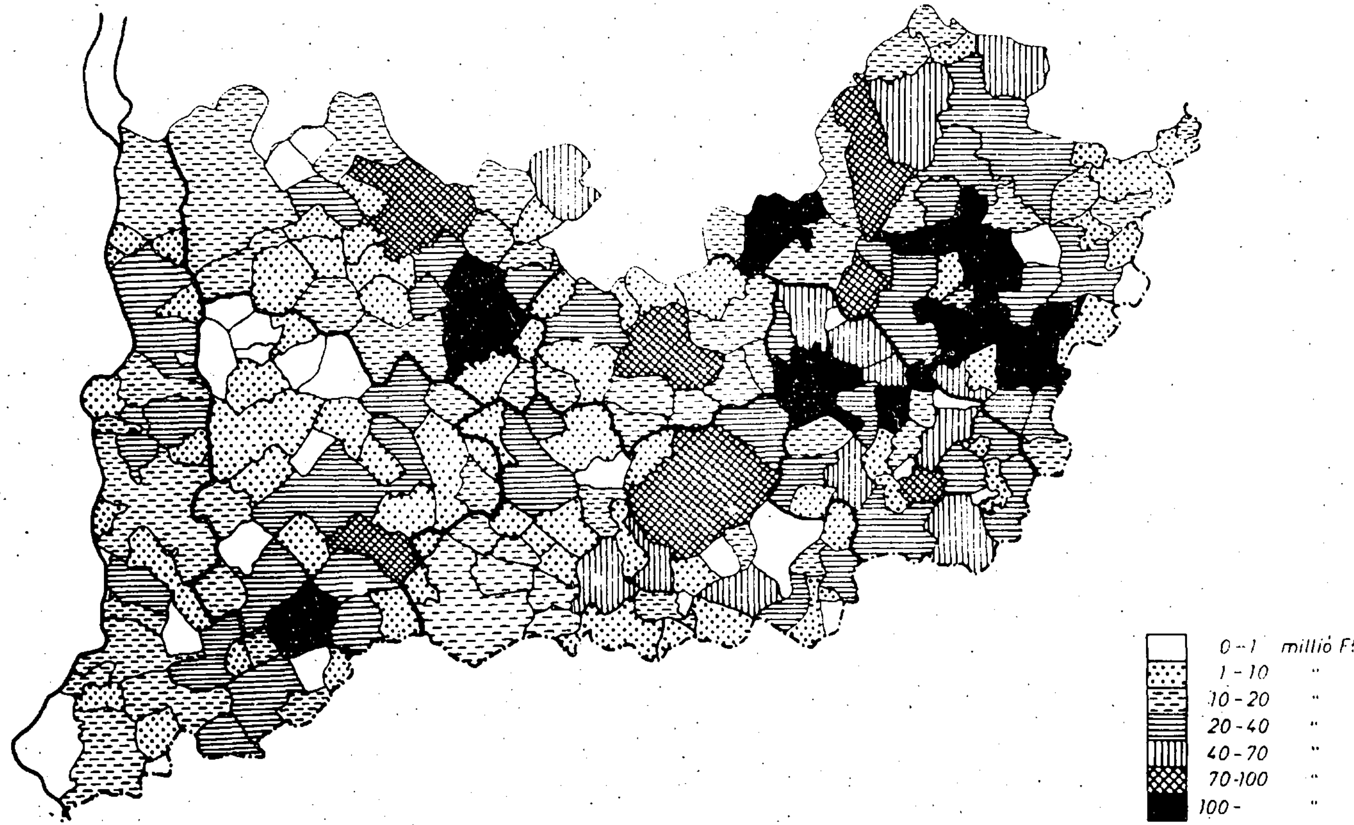


Figure 6. The raw material supply of the food industrial centers of the southern part of the Great Plain (1970).

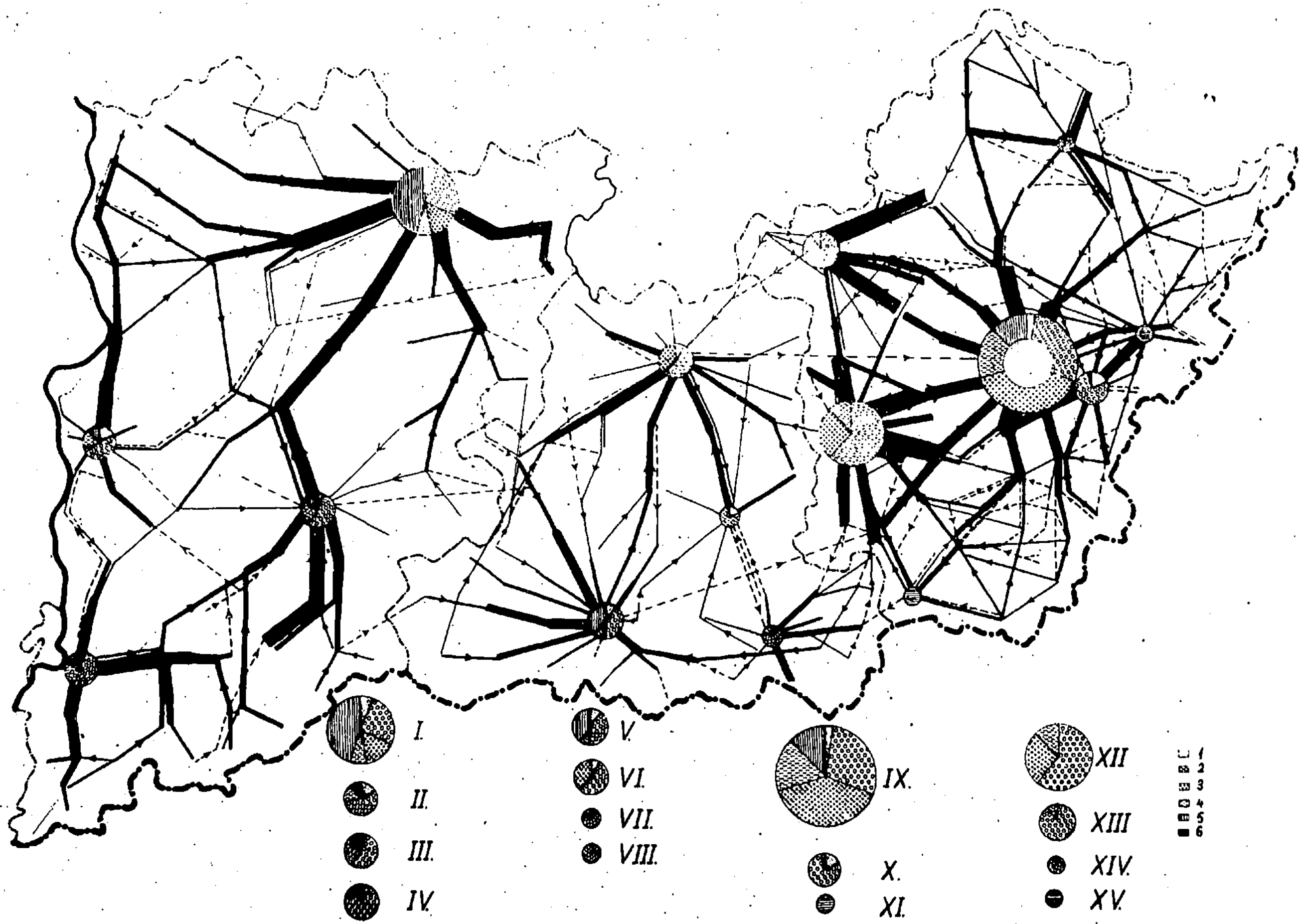


Figure 7. The territorial structure of the microregions. 1. outer zone, 2. transition zone, 3. intermediate zone, 4. inner zone, 5. inner zone thus these data do not show where the settlements in question belong; on the other hand the territorial differences are expressive of the social and economic life of the different settlements as fewer inhabitants of unfavorably situated settlements travel regularly than of settlements near the towns. Three categories can be distinguished on the map:

— *settlements* near centers or settlements with excellent rail or road connections *in which the ratio of regular commuters is high,*
— *medium*
— *low*

5. Buying up of agricultural products for the food industry together with the market supply show certain differences between the settlements. The food industry, depending on natural and social factors, seeks to obtain its raw material from as near as possible. This is understandable since nearness of the source of raw materials means reduction of the transportation costs and of the loss by perishing. Thus the nearer settlements contribute to the supply of goods in a greater ratio as compared with the population or the surface area. Even if this situation does not always prevail consistently but often through many contradictions and in a far more complex form than here described, for very many factors are involved, it expresses the existence of an important tendency.

The gravitation of the settlements is far more clearly shown by the direction and bulk of the market supply than by the buying up of agricultural products for the food industry. Unfortunately the survey could not be carried out in some settlements and so our material is not complete. Still it is usable as it is because the material of most of the centers has been worked up and it may help decide where some peripheral settlements belong. Spatial division of the market supply also shows considerable territorial differences. The inner zones which furnish the largest amount of market supply manifest themselves clearly around the centers. From the next zones a much smaller supply is transported to the centers, and finally the third zones are divided areas which send their supplies to two or more centers.

It is easy to see the similarity between the above-mentioned factors; they show essentially the same kind of territorial differentiation due to similar laws. This is no mere chance as these factors reflect manifestations of the social division of labor and also the components of the internal economic, social, and cultural life of the areas, and what is very important to us, the territorial differences. This is what makes a mechanical combination of the factors possible because not the factors themselves are assessed together here but the intensity of the territorial variation of the factors. For the combination of the factors of each settlement and the ascertainment of the types it is advisable to use an electronic computer to make the work faster. We did this work also with the aid of such a machine.

Evaluating the factors in combination we could establish the following types of settlements:

1. *The centers of the microareas* (together with the agglomeration

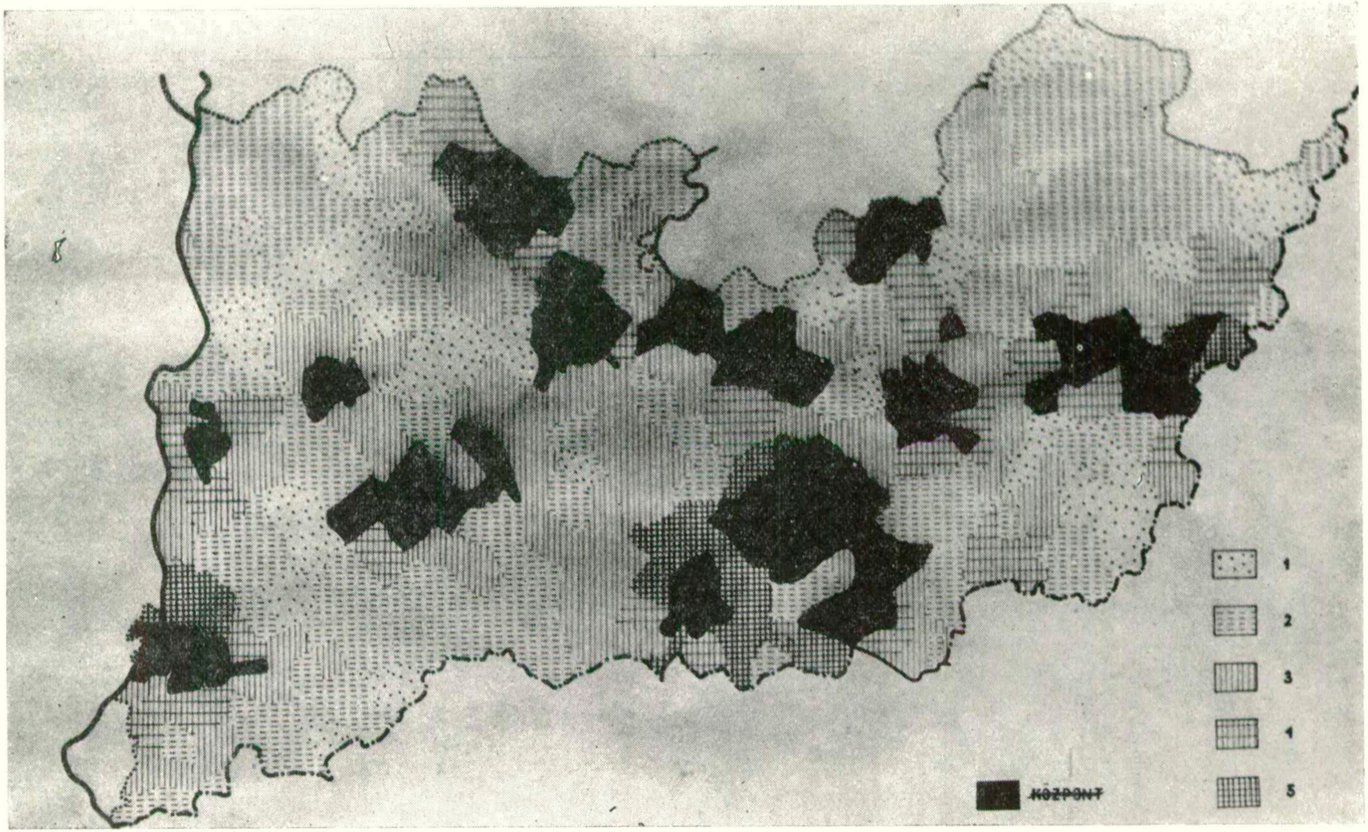


Figure 8. Frequensy of buses going to the centers.

zone). Owing to their dynamic (industrial) development their influence on the surrounding settlements is noticeable:

- they have better developed attraction spheres than those of the microcenters,
- they are traffic centers,
- they are the purchasers of the agricultural products,
- they attract the population of the surrounding settlements and their migration balance is therefore positive or will be so in the near future,
- they are centers of commutation.

We have not distinguished the agglomeration zones from the centers as their ties are very close and as in the case of Szeged sooner or later they will merge also administrationally.

2. *The inner zone* is the zone of settlements that have very close and varied ties with the centers:

- in it hegemonic attraction of the center is noticeable,
- the transportation facilities of the settlements are excellent or good,
- population decrease is less than the average of the Southern Plain, and out-migration has in recent years considerably slowed down,
- the number of daily commuters is fairly large and the direction of commutation is from home in the smaller settlements to the center and back again.

These facts clearly show the influence and attraction of the centers.

The settlements of the inner zone can be divided into two groups; the settlements of the first group have very strong ties with their centers of attraction, the settlements of the second group have somewhat weaker ties. The difference does not only depend on the strength of the ties but also on the various degrees of development of the settlements. While only settlements of the second group are found around smaller centers like Kalocsa, Kiskunhalas, Szentes, Orosháza, etc., settlements of the first category are mostly found around Szeged.

3. *The transition zone.* Here belong settlements whose gravitation to their respective centers is clearly seen but whose indexes of factors are very different, varying between the highest and medium. As regards the course of development the settlements belonging here come always nearer to the criterion of an inner zone as the centers become more and more important. The settlements of the transition zone are characterized by the following features:

- usually dominant, sometimes hegemonic, attraction prevails,
- tranportation conditions are medium good,
- in respect of market supply the zone is a secondarily attracted area, the agricultural products of the area are sent to different places,
- the changes in the number of population are generally unfavorable. In the inner zone the decrease in population is slight, but here relatively higher.

— the extent of commutation is much smaller here than in the inner zone but it is still multidirectional. Intensive migration of the population indicates that there is a more considerable manpower reserve here than in the inner zone and the proportion of the agricultural population is also much higher.

4. *The outer zone*. In the case of the settlements belonging here not only is the intesity of the abovementioned factors low but they are also often divided as regards their direction. The influences of several centers make themselves felt and occasionally they overlap. The main characteristics of the settlements of the inner zone are the following:

— the transportation conditions are unfavorable,

— dominant or multilateral attraction prevails,

— the volume of market supply from this area is inconsiderable, the agricultural products of the area are exported in several directions,

— the number of the population is sharply decreasing (unless otherwise influenced by some local factor). Out-migration from the area was considerable earlier and with the exception of those parts with intensive agriculture it has been moderated less than the average of the Southern Plain, and the proportion of those engaged in agriculture is higher than in the case of the average of the mesoareas,

— the proportion number of daily commuters is small and so the proportion of the regular travelers in the population is also low. On the other hand, the number of weekly commuters is relatively high.

5. *The intermediary area*. This is not an unbroken zone. Here belong areas in which

— the gravitation to any center cannot be ascertained with certainty,

— the transportation facilities are very poor,

— the gravitation of the settlements is not reflected in the marketing of goods or the transportation of agricultural products, or else the marketing of goods differs from the orientation of the other factors,

— the population indexes of the settlements are all unfavorable.

Here belong administrationally parts of Bács-Kiskun or Békés county, otherwise not belonging to the mesoarea.

According to the principles described above, the settlements of the Southern Plain can be divided into categories and zones that differ from each other in many essential features. First of all they play different roles in the division of labor that has developed between the centers and their neighborhood. This territorial division is important from several points of view. On the one hand it reflects exactly the territorial structure of the microareas, on the other hand it greatly facilitates the delineation of the area boundaries.

The inner zones around the centers are so closely linked with the centers that their belonging together cannot be doubtful even from the point of view of the microareas. The extent of the inner zones depends on the size of the centers and their economic, social and cultural influence. Where the centers lie nearer to each other, these zones are in direct contact. In this case the meeting of the zones — if they belong to the influence spheres of two different centers — coincides with the boundaries of the microarea. This, however, is a rare case; more frequently the outer and intermediary zones are in contact which do not reflect the area boundaries nearly so sharply. At any rate we have to look for the boundary areas in the outer and the intermediary zones. This zone can therefore rightly be called the boundary zone. Its spread is not uniform in the Southern Plain. Depending on the size of the centres it includes smaller or larger areas, e.g. smaller in Csongrád county and larger in Bács-Kiskun county and Békés county.

For distinguishing the outer and the intermediary zones and for ascertaining to which area the settlements belong factors must be found that are essential from the point of view of economic and social life and at the same time indicate the connections of the different settlements. For this purpose we have considered the following factors:

1. the attraction spheres of the centers,
2. the transportation facilities of the settlements,
3. the direction of the movement of the agricultural products (including the market supply),
4. the production structure of the agriculture,
5. the factors of physical geography (above all the soil, hydrography, relief, and mineral resources),
6. the administrational division.

Unfortunately we must leave out of account some factors as no full information was available for the whole area of the Southern Plain for instance as regards the direction of commutation or of migration in the different settlements. The data mentioned here could be collected only in some places for our analysis. Experience shows that omission of the above factors does not essentially modifi either the methed or the exactness of defining the area boundaries.

The above factors do not always coincide territorially. Ovelapping is frequent and therefore it is reasonable to reckon with all the factors, although their roles are different.

1. The attraction spheres of the centers correspond to the data used for the definition of the zones, but the emphasis here is not on the intensity but on the direction of the attraction. This factor cannot be neglected as it indicates exactly where a settlement belongs.

2. The summing up of the factors used in assessing the transportation facilities is no suitable basis for the direct delineation of the boundaries as it does not show the directions of attraction; on the other hand, an element, the frequency of buses and the number of bus routes, can very well be used for this purpose. The density of routes indicates the links of the different settlements and helps decide the question where they belong.

3. The direction of the movement of agricultural raw materials has already been mentioned in connection with the attraction spheres, but

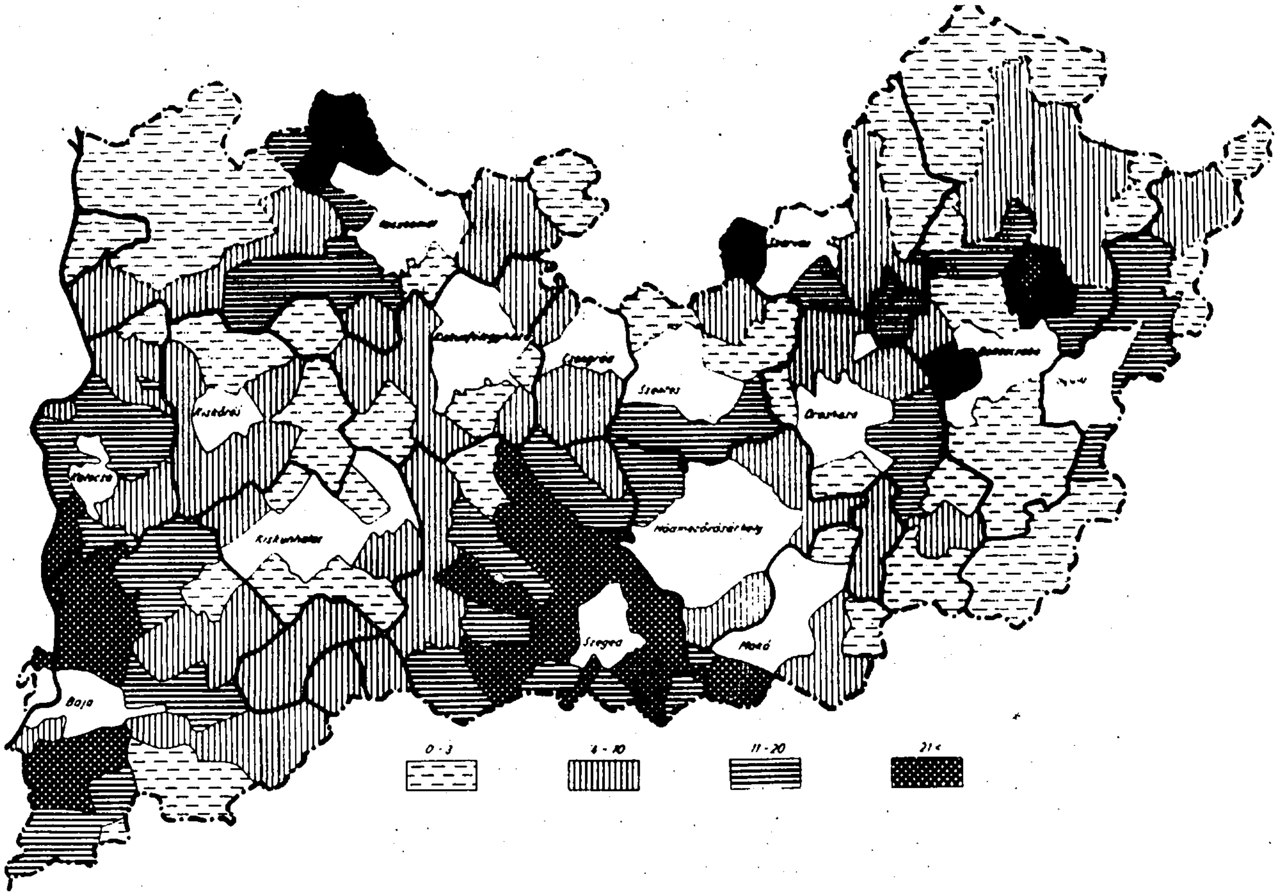


Figure 9. The main destinations of the raw material consignments for the food industrial centers of the southern part of the Great Plain (1970).

1. milk industry, 2. meat industry, 3. poultry industry, 4. flower-milling industry, 5. canning industry, 6. sugar industry. I = Kecskemét, II = Kalocsa, III = Kiskunhalas IV = Baja, V = Szeged, VI = Szentes, VII = Makó, VIII = Hódmezővásárhely, IX = Békéscsaba, X = Gyula, XI = Mezőhegyes, XII = Orosháza, XIII = Szarvas, XIV = Szeghalom, XV = Sarkad

here we are not so much concerned with the strength as with the direction of the main attraction.

4. The structure of agricultural production appears as an additional factor. It is used differently from the other factors as the directions of attraction are out of the question here. The use of this factor is justified by the fact that it belongs to the production pattern of the areas and occasionally it helps decide where the different settlements belong. This is however, possible only when and where the economic microareas coincide with the agricultural areas, that is where two regional units with different types of production meet. Otherwise, that is when the type of agriculture is the same in both regional units, this factor falls away automatically.

5. The physical factors play a role in the definition of the area boundaries only occasionally, and then mainly on account of the soil, relief, hydrography, and mineral resources. The types of soil exert their influence essentially through agriculture, but the role of relief, water supply, possibility of irrigation, and exploitation of the mineral resources must not left out of consideration either. It is well known that the exploitation of such natural resources, e.g. the exploitation of crude oil and natural gas, has changed also the economic relations of the settlements concerned. In determining the area boundaries the natural factors are used in a similar way as in the case of the classification of agriculture into types of production.

6. The question where a settlement belongs administrationally is often decisive, especially where the overlapping of other factors has a neutralizing effect. The reverse, also occurs when the administrational ties are weaker than the other factors of attraction. This is why among other factors the administrational boundaries must also be taken into account.

In the border zone delineated earlier, the orientation of each settlement must be determined with an electronic computer on the basis of the factors mentioned. In the case of a mechanical combination of the factors we get essentially the same result, but the use of a computer speeds up the work.

The differentation of the microareas is not complete with the determination of the area boundaries although the remaining part of the job is much simpler than in the preceding stages. So far we have designated the centers and the zones surrounding them and outlined the attraction areas of the centers. In the following we have to decide which are the centers that form one microarea together with the area under their influence. Thus we have to reckon here with whole territorial units and not with single settlements. Classification of them into microareas can be done on the basis of the following points of view:

1. identity of the production profiles,
2. strength of production and transportation relations,
3. attraction relations of the areas belonging to the centers,
4. common features in the trend, rate, and peculiarities of economic

development (e.g. similarities in the problems and in their solutions),
5. common features in the natural possibilities (above all the soil hydrography, and mineral resources),
6. administrational boundaries (county boundaries).

It appears from this list that the question here is not such or such manifestation of the social division of labor, but division of labor itself as the most important factor of organization into economic areas. We cannot expect all factors to support uniformly the orientation of a given territorial unit. Unfortunately the factors cannot be weighted because their role varies with the cases. For instance the belonging of the region of Szeged and Makó to one microarea is not supported by similarity in the production profile, identical problems of development, or identity of the natural conditions, yet Makó and its region belong to the attraction sphere of Szeged. Very close production, transportation and social relations have developed between the two regions. Roughly similar is the case of Hódmezővásárhely. The difference is only that the relations of this town with Makó are still closer and there is a greater similarity of development between them. This means practically that Makó and its region cannot exist as an independent microarea in the shadow of Szeged. Otherwise the extent of its area does not make it possible either. In the case of the regions of Baja and Kalocsa — in contrast with the example of Szeged — nearly all factors support their belonging to one economic area. Thus very close relations have developed in every respect between the two regions; the production profiles of the two regions agree, the conditions of agricultural production (possibility of irrigation, soil conditions, etc.) are very similar, and the trends as well as the problems of development are largely identical.

There is no need to continue the enumeration of these factors as they will be dealt with together with the delineation of the economic areas. The examples mentioned serve as an illustration of the fact that the factors mentioned in themselves do not decide anything and in this case the mathematical formula cannot replace analytical work, which means that the orientation of the territorial units involved must be decided separately in each case with the help of these factors, for there is no other way.

Classification of the territorial units into economic areas is no problem where the relations of the centers are close owing to their nearness to each other. This is fortunately the case in most parts of the Southern Plain, but in other parts of the country, where there is a territorially more complicated system of the social division of labor, it is no easy task to distinguish and place the different territorial units. This is why spatial structure investigations must be carried out, and the economic and social p[illegible]s in the microareas must be explored, and each case must be examined separately on the basis of the facts as in the Great Plain.

Summerizing we can say that the determination of the areas consist of three phases: 1. the inner territorial structure of the areas is determined, 2. the areas belonging to the given centers are determined, and finally, 3. the territorial units determined are classed into microareas.

This method was successfully applied to areas of the Southern Plain and the same method can probably be used with minor modifications or amendments also in other areas but as the method is above all determined by the peculiarities of the area under examination and the tasks of research, it is advisable to check the applicability of the method developed under other conditions.

Subjectivity or errors are of course not excluded, but correct utilization of the evaluated statistical data and control of the results limit this possibility to a minimum. Investigating the microareas the researcher comes much nearer to reality than with the method of determination "from above downward" where the average figures often cover up the territorial differences that the author tried to point out by the method described above and on which later the higher levels of the economic areas can be built.

2. **Definition of the economic microareas of the Southern Plain**

The economic areas can be defined with the help of the method described above on the basis of the economic and social processes discussed in the previous chapters. The material collected so far needs to be completed only in one respect, i.e. with a survey of the conditions of industrial development in the different economic areas.

There is a difference between the microareas not only as regards the structure and developmental dynamics of industry, but there are also essential differences in respect of the possibilities of industrial development. This is understandable as all the processes are determined by the same socio-economic and natural factors.

For surveying the possibilities of industrial development we have used in addition to the material presented so far the information booklet prepared by the Chief Department for Area Development of the Ministry for Construction and Town Development. This booklet, entitled "The Choice of Sites for Industrial Establishments", is the first and only survey that using eight factors for 64 branches of industry determines the effect of the conditions for each settlement in the whole country. The factors of establishment and their power can be qualified with the help of a scale of five grades and represented in a star diagram and so the different types and territorial differences can be clearly shown. The fourth and fifth grades are treated in the survey as dominant factors. The degree of efficacity of the factors of the branches of economy and the different branches of economy worth developing can be combined in a column diagram and their combination provides an excellent possibility for characterizing the microareas and for showing the differences in the tendencies of development.

The boundaries of the microareas of the Southern Plain

On the basis of a comparison of the factors mentioned above we could outline the different microareas. They are the following:

a) *The region of the Danube;* the western and southern boundaries of the area are given, so the problem is only the drawing of the eastern and northern boundaries. The factors used indicate in most cases clearly enough where a given settlement belongs. Overlapping occurs in the case of the following settlements:

Császártöltés; from the point of view of attraction and transport it belongs to the region of the Danube. According to the majority of the factors, however it belongs to the area of Kiskunhalas and so we have assigned it to the latter.

Rém; the factors are rather varied, but considering the increasing influence of Baja we have assigned it to the region of the Danube independently of its administrational status.

Kunbaja, Csikéria, Bácsszőlős; here, too, the overlappings are rather strong. Considering the growing influence of Bácsalmás by which it attaches the abovementioned settlements to itself and thereby to Baja, it would not be suitable to separate these settlements from their center. Drawing the northern boundary of the area in the region of the Danube presents a problem because the areas north of Dunavecse do not belong to the Southern Plain; consequently the settlements of this area cannot be attached even to the microarea. However, if we are to prove this, it is not enough to examine the problem from only one side, the investigation must be extended to the area of Dunaújváros and Budapest, too, i.e. the status of these settlements must be explored also from the side of the central area.

Besides those mentioned, there are several other settlements with overlapping, (Jánoshalma, Mélykút, Tompa, Kecel) but this does not obscure their status and cannot influence our classification.

b) *The Danube—Tisza interfluve;* similarly as in the above-mentioned cases, difficulties arise in drawing the eastern and northern boundaries of the area. It is distinguished from the area of Kecskemét first of all by its conditions of attraction, transportation, and its administrational status. The physical geographic conditions and the profile of agriculture in the two contiguous areas are essentially identical, for which reason these factors must be dropped when we want to determine their boundaries. Essentially similar is the situation in determining the eastern boundary with the difference that there is much overlapping in the transportation of agricultural goods in the north, but there is none in the east.

In this area the problem settlements are the following:

Fülöpszállás; which administrationally belongs to the district of Kiskőrös, yet on the basis of all factors (except for the agricultural profile) gravitates to Kecskemét.

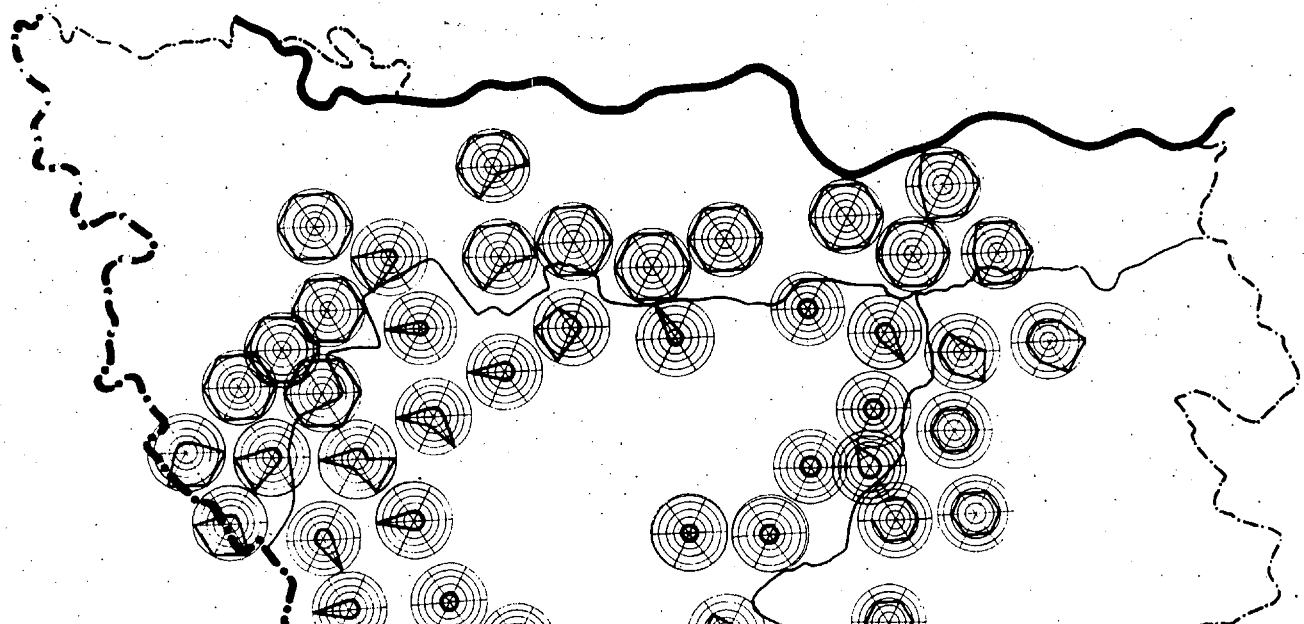
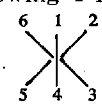


Figure 10. Definition of the microregions I. The riverside region of the Danube (the explanation is valid also for the following 4 figures)



1. agricultural line, 2. physical geographic conditions, 3. spheres of attraction, 4. transport, 5. buying up of agricultural goods, 6. administration

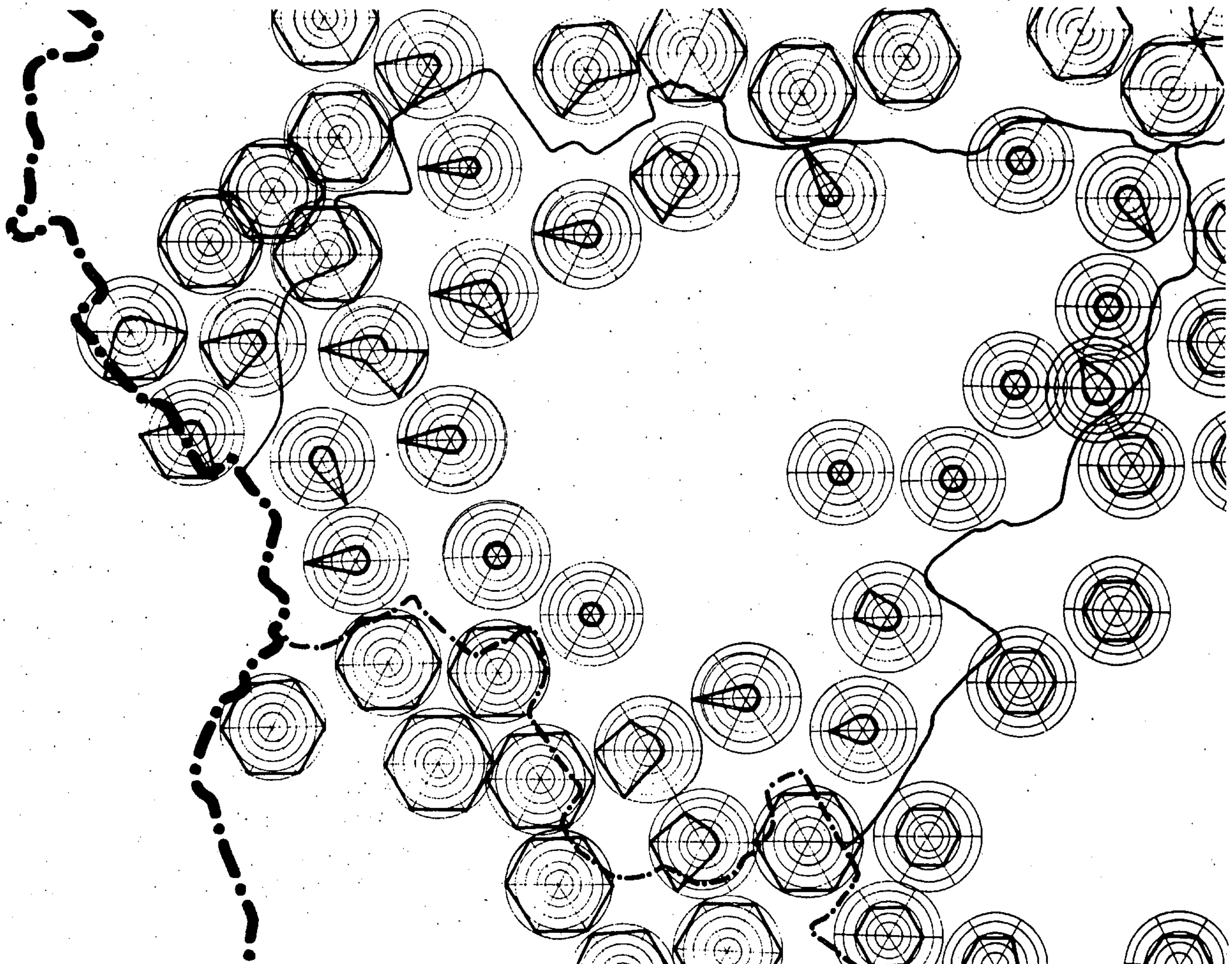


Figure 11. Definition of microregions II. Middle portion of the Danube—Tisza interfluve (For explanation see Fig. 10)

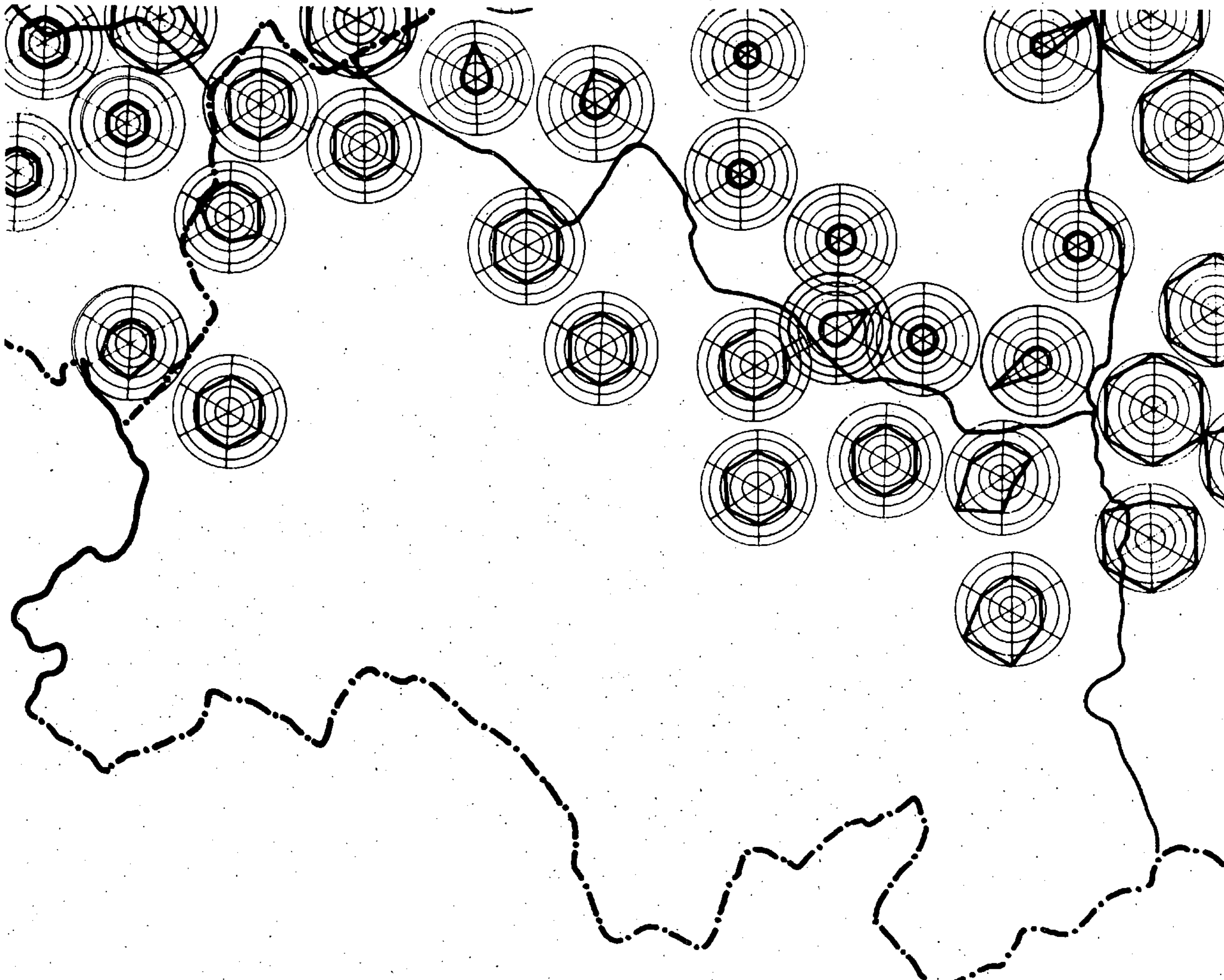


Figure 12. Definition of microregions III. The microregion of Kecskemét (For explanation see Fig. 10)

Szank and Jászszentlászló, which from the point of view of transportation and the buying up of their agricultural products are oriented toward Kecskemét, but on the basis of the rest of the factors belong to the area of Kiskunhalas.

Kömpöc and Csólyospálos, which according to most factors belong to the area of Szeged but from the point of view of the boundaries of the county (the baundaries of the microareas do not cross the county boundaries anywhere) the two settlements have been classed in the area of Kiskunhalas.

c) *The area of Kecskemét.* Similarly as in the case of the area in the region of the Danube, it is difficult to decide where Kunszentmiklós and Kunpeszér belong. There is practically not one factor which connects Kunszentmiklós and the neighboring settlement to this microarea, so this part in all probability belongs to the central area.

Then it is an interesting problem to decide where *Nagykőrös* and some neighboring settlements belong. In our opinion the area in question, on the basis of its identical industrial and agricultural profile and the close ties between the two towns, is an integral part of the Southern Plain.

Otherwise the determination of the boundaries of the microarea of Kecskemét presents no particular problem because overlapping of factors occurs only in *Bokros* and *Gátér,* but the question where they belong is decided for both settlements by the county boundary.

d) *Along the walley of the Tisza* two microareas have developed, that of Szeged and that of Szentes, Outlining them we encounter the following problems:

As in the case of the microarea of Kecskemét, it is not easy to draw the northern boundary of the microarea of Szentes. The difficulty is to determine the status of the region of Tiszazug and Kunszentmárton. In our opinion these areas belong to the Southern Plain, but for a final judgment the problem must be examined also from the side of Szolnok county, i.e. the mesoarea of the northern part of the Trans-Tisza Region.

Drawing the southern boundary of the microarea of Szentes we also find several settlements in which the factors overlap.

From the point of view of administration and the transportation of agricultural products *Székkutas* and *Mártély* belong to the microarea of Szentes, but all the other factors uniformly attach the two settlements to Hódmezővásárhely, i.e. the microarea of Szeged. In the case of Mártély it must also be taken into consideration that it is a holiday resort of Hódmezővásárhely.

In the case of *Baks* and *Pusztaszer* there are only minor overlappings which do not weaken the attachment of these settlements to the microarea of Szeged.

The area of Szeged has practically been outlined in the foregoing and only the drawing of the eastern boundary remains to be done. Overlappings of factors are found only in the case of only a few settlements (e.g. Nagyér, Ambrózfalva, Pitvaros, Csanádalberti). These overlappings

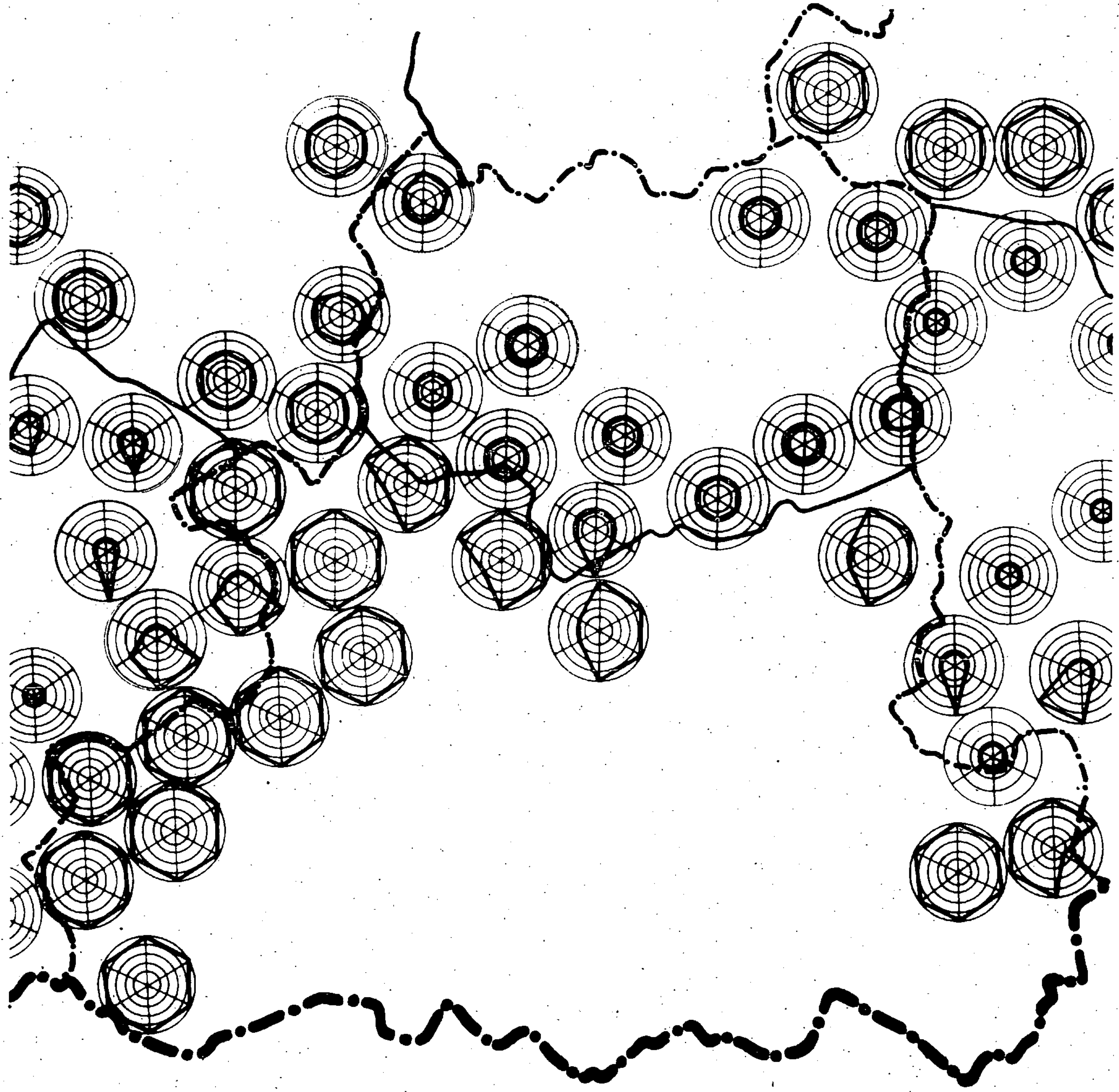


Figure. 13. Definition of microregions IV. Microregions of the Tisza (For explanation see Fig. 10)

are of little importance and so it is not reasonable to deviate from the county boundaries.

e) In drawing the boundaries of *the area of Orosháza* in the north (where the attraction of Orosháza is fully felt) nearly all the factors uniformly make the situation easier by distinguishing the areas sharply from each other. In the district of Mezőkovácsháza in the southern part of the area there are no major industrial centers and therefore a zone of overlapping has developed at the northeastern and western boundaries. On the basis of the administrational boundaries, the buying up and transportation of agricultural products, the mobility of the population, etc., we have ranged it with the microarea of Orosháza because these features show similarity with the rest of the territory of the district.

The boundaries of the microarea of *Békéscsaba* are for the most part given after delimitation of the area of Orosháza. Certain modifications must be made along the northern boundary because the settlements involved — Bucsa, Ecsegfalva, Kőrösnagyharsány, Biharugra — do not belong to the Southern Plain but to the northern Trans-Tisza Region.

The character of the economic microareas

Except in the case of a few settlements the microareas could be delimited with full certainty on the basis of the factors discribed above. Drawing of the boundaries does, however, not mean that the area delimited really belongs to a given microarea. To prove this we must examine also the inner social and economic processes and structures in the area. The economic areas usually differ from each other as regards their physical geographic conditions, agricultural and industrial profiles, and the possibilities and trends of agricultural development. Owing to their territorial differentiating force these factors indicate on the one hand the differences between the areas, on the other hand the inner unity of the microareas. For this reason they must be taken into consideration in delimiting the microareas.

We have spoken of the physical geographic conditions before the chapter on agriculture. Here we have to deal with them, although more shortly in order to make clearer the differences between the areas. This unfortunately implies repetition which cannot be avoided.

The area in the region of the Danube

The valley of the Danube as a separate territorial unit constituting an important part of the area was formed by the surface-shaping effect of the river water at the end of the Pleistocene. In the area eroded by the Danube young (Holocene) sediment (sand, silt, and clay) was formed by the Danube. Owing to the loess washed in and the sediment of clay

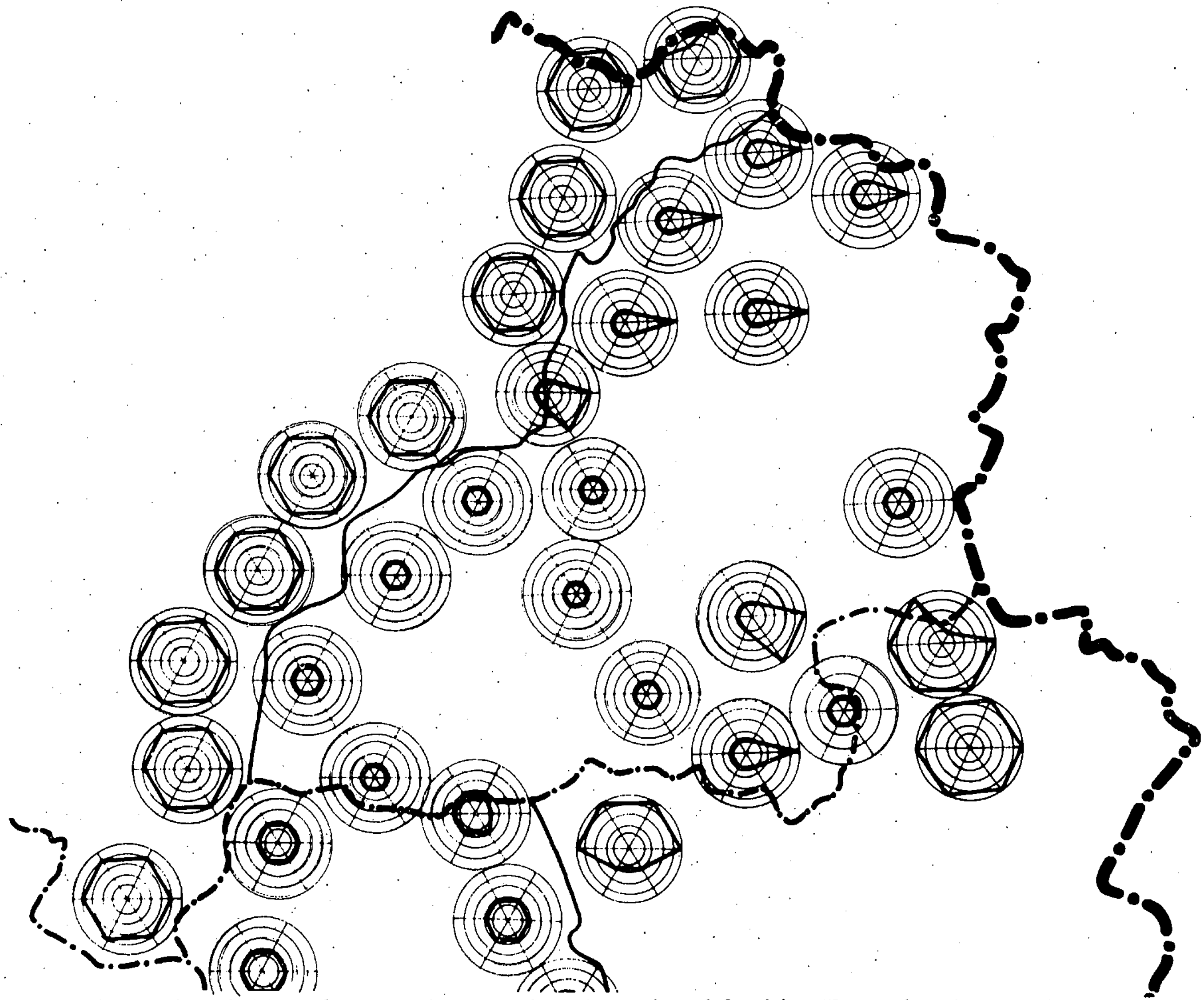


Figure 14. Definition of microregions V. The microregion of Orosháza (For explanation see Fig. 10)

surfaces of the Pannonic epoch, silty clay or clayey silt top layer formed besides the coarser-grained deposit of the river water.

Differently from this, chiefly loose waterpermeable eolic sediments are present in the surface structure of the *rolling plain in the Danube—Tisza interfluve,* which constitutes about one-third of the Southern Plain. Since the last interglacial period the Danube has not shaped the area with its erosive activity. In the last periglacial and the dry periods of the Holocene the wind reshaped the surface to such a considerable depth that the area lost its alluvial character at least in its surface layer.

On the basis of the quality of the surface sediments and the morphological qualities, the rolling plain can be divided into a northern and a southern part. While in the northern part quicksands, sandhills, dunes and deflationary depressions are the dominant surface features, in the southern part there are loessal sand and relatively even, level surfaces, which are favorable for agriculture.

The eolic formations with two different sizes of granulation have produced two peculiar and very different kinds of soil, which makes a great difference in the agricultural production of the region. In the northern part of the rolling plain, usually on thick sand layers, poor quality soils have formed that are completed by the frequent occurrence of solonchak meadow soils among the types of sand. Here the relief form is of a decisive character from the point of view of the development of subsoil water and the development of soils.

On the loess-covered surface of the southern part of the rolling plain there are medium packed, good quality, easily cultivable lime deposits and chernozem soils with high organic matter content.

The soils of the Danube region are, as opposed to those of the rolling plain in the Danube—Tisza interfluve, mainly alluvial soils, meadow chernozem, in some depth salt chernozem and solonchak-solonetz. With the exception of the last named, the organic matter content of these soils is high and accordingly they have a fairly high gold crown value. (Gold crown is the unit of land value in Hungary.) They are relatively easily cultivable, and as their water economy is excellent both as regards surface water and depth water supplies, advanced irrigation culture has been able to develop on them.

The influence of the different physical geographic conditions manifests itself above all in the structure of the agriculture and the differences in the production profiles. On the rolling plain of the Danube—Tisza interfluve the soil conditions are favorable for vine and fruit-growing. Rye and corn (maize) grow well on this land, and there are beautiful meadows and pastures in the deflationary depressions. Generally speaking, the conditions are less favorable for growing juicy fodder plants than in the area along the Danube. Owing to the low organic matter content of the soil, the land has a high manure requirement, but the low level of the cultivation of juicy fodder plants and the poor quality of the meadow pasture hinder increasing of the stock of cattle. This vicious circle affects also the average yield of vegetal cultures. The possibilities of irrigation are very limited. On the other hand in the area along the Danube, the possibilities of irrigation are excellent and the soil and climatic conditions are favorable, for the cultivation of corn and wheat and for the general use of irrigation farming.

In the southern part of both areas the territorial differences are obscured. Vine and fruit appear along the Danube and on the loessial plain wheat and corn are grown over a wide area. In spite of this there are striking differences in the areal surveys of the branches of cultivation; in the area along the Danube the proportion of plowlands, pastures, gardens, orchards, and vineyards does not exceed the average proportion in the whole Southern Plain, and the proportion of meadows is scarcely smaller, while in both microareas of the sandy rolling plain the proportion of plowlands is very low, but the proportion of vineyards, meadows, and pastures far exceeds the average of the Southern Plain. In the proportion of the irrigated areas the differences are, for readily understandable reasons, much greater. It is natural that the differences in physical geographic conditions are reflected in the differences in the crop structure.

Comparing the area along the Danube and the area of Kiskunhalas, we find differences not only in the natural conditions and agricultural production but also in the structure, development, and perspectives of its industry. Among the factors influencing or determining the establishment of industry in the area along the Danube are water, education, and an urban background. Besides these, powerful factors are transportation and labor force. In contrast to this, only the labor force and the urban background can be mentioned particularly as dominant factors in the area of Kiskunhalas. Besides this, if we take into consideration that the factors of the establishment of industry are not of the same importance, the difference is still greater. In the area along the Danube the ease of water supply and mass transportation by water mean much better perspectives for the development of industry than the labor reserve of Kiskunhalas.

The factors favoring the establishment of industry in the area along the Danube make possible the development of most industries, e.g. the conditions are favorable for the development of machine industry, building material industry (manufacture of concrete blocks), crude oil processing, dye and household chemical industry, clothing, leather, meat, and other food industries. Although the industries mentioned have excellent possibilities, their establishment is conditional, which means that in the establishment and development of industry national interests must be considered. It would not be suitable to utilize the factors favoring the establishment of industry (viz. labor force) for industries that can be established under the same conditions in a neighboring area if at the same time there remained no possibility for the development of the branches with high water requirement that are of great importance for the whole country. Thus the basic difference between the two areas is that while in the area of Kiskunhalas with the exception of food industry and a few branches of industry with high labor requirement no nationally important industry can be established, in the area along the Danube there is a possibility for developing the branches of industry of national importance. This fact determines not only the rate but also the direction of the economic development of the two areas.

From among the areas of the Southern Plain both the area of Kiskunhalas and that of Baja belong to the less developed areas. The ratio of development of the industry in the area along the Danube is 0.378, that of the area of Kiskunhalas 0.238.

In the determination of the level of development more or less the same ratios are characteristic; this level in the region along the Danube is 0.0081, in that of Kiskunhalas 0.0051. These figures show that the values of both regions are well below the average of the Southern Plain. In respect of the rate of development of industry, the area of Kiskunhalas has far surpassed the region along the Danube. (The intensity of development in the case of the former is 3.86, in the case of the latter only 1.72. This can be explained first of all by the fact the area of Kiskunhalas started from a much lower level and there was also more labor force for a quick development of some branches of industry with high labor requirement.

Going on with the comparison of the region of the Danube and the Kiskunhalas area, we find important differences in the changes of the number and occupational distribution of the population. The changes in the number of population roughly agree in the two areas, but natural growth is much higher in the Kiskunhalas area (2.5% between 1960—70). Outmigration is also higher (7%). The proportion of those engaged in agriculture is nearly 10% higher on the rolling plain than in the contiguous areas.

The differences between the two areas clearly prove that the region of the Danube is in all respects a relatively well definable independent economic microregion which is developing as a territorial unit and which at the same time in many respects differs from the contiguous Kiskunhalas area.

2. The arguments mentioned so far are not sufficient to prove the existence of a distinct Kiskunhalas area because by separating it from the region of the Danube we have not yet drawn its boundary in the east and in the north. In the following we are going to compare it with the economic microregion of Kecskemét emphasizing the differences.

The essential difference between the two microregions is in the level of development and structure of industry. The measure of development of the Kecskemét area, 0.981, comes near to the average of the areas, while the level of Kiskunhalas is far below this. Similar is the situation with the index of its level of development, which is 0.0210, i.e. four times as high as that of the neighboring area. In respect of the rate of development the situation is reversed.

The differences in the factors of the establisment of industry are also essential. In the Kecskemét area there are four dominant factors (labor force, transportation, education, urban-like background), whereas in the Kiskunhalas area only two factors of the establishment of industry have the criteria of dominant factors. This means not only that the Kecskemét area has more important and more diversified industry, but its conditions for the development of industry are also much more favorable. In this area, not counting the branches of industry with a high water requirement, nearly all branches of industry can be established with high effeciency, especially the branches of machine industry, which have a high manpower requirement. Development of the food industry has about equal possibilities in both areas.

Although there are many similar features in the industrial profile of the two microregions (in the food industry), the differences are far more considerable. The microregion of Kecskemét is distinquished in the Southern Plain by its machine industry, canning industry, and several branches of industry that do not exist or are on a smaller scale in the Kiskunhalas area.

The differences in the level of development are reflected in the composition and changes in the number of the population. In the microregion of Kecskemét the number of the population rose between 1960 and 1970, while in the area of Kiskunhalas it fell considerably. The proportion of those engaged in agriculture in the latter area is 20 per cent higher than in the former. There is a similar difference in the proportion of urban population (in 1972!). These facts show the differences in the tendencies of development of the two areas.

Thus the Kecskemét area represents a much greater potential than its southern neighbor. It is therefore understandable that the attraction sphere of Kiskunfélegyháza, but especially the attraction sphere and the food industrial raw material basis of Kecskemét are territorially larger than the microregion. At the same time this does not diminish the possibilities of development and the independence of Kiskunhalas. Owing to its rapid development in the last decade, Kiskőrös has evolved a distinct attraction sphere which continues to expand and is more and more clearly reflected in the life rhythm of the surrounding villages and in the migration of the population. This proves that the area has its own peculiar perspective and rate of development (both in industry and agriculture). Owing to economic and social processes the area has its own peculiar life rhythm. In fact this is its most essential trait which distinguishes it from all the neighboring areas. On this basis the Kiskunhalas area, like the region of the Danube, can rightly be regarded as an independent territorial unit.

3. In the valley of the Tisza two microregions have developed, the comparison of which is first of all necessary because the microregion of Szeged is so different from its western and eastern neighbors that its delimitation presents no particular problem, whereas it agrees in many respects with its northern neighbor, and their differentiation is therefore more difficult. The physical geographic conditions of the two economic regions of the Tisza river valley are essentially the same. The valley of the Tisza is the separating belt between the rolling sandy plain in the Danube—Tisza interfluve and the loessal plain of Békés county.

The Tisza river valley is one of the lowastlying areas in the Southern Plain. Its surface formations, with few exceptions, are Holocene sediments.

On the eroded surface of the Holocene sediments first coarse sand, then always finer river sand, then silty fine sand, fine sandy silt, clayey silt, and finally meadow clay were deposited. The finer and finer quality of the deposits from below upward reflects constant decrease of the transporting power of the river water, but at the same time it also suggests the presence of considerable amounts of subsoil water.

The territorial distribution of the different qualities of sediments is also irregular. As we move away from the present river walley the quality of the sediments changes. In the immediate neighborhood of the river alluvial silt and sandy silt derived from annually repeated floods can be found everywhere. Farther away from the river and near to the alluvial silt, meadow clay formed in large patches. After the receding of the floods extensive alkalination took place (e.g. south of Hódmezővásárhely). In the parts farthest from the river the flooding of the river made swampy also the uppermost infusion loess cover of the Pleistocene. In this region layers consisting of fine silt and rich in humus (black earth of high nutritive value) were formed at the time of floods.

The surface and under-surface water reserves satisfy the water requirement of the agriculture of the area. Thus, utilizing the possibilities of irrigation, a varied agricultural structure can develop here.

Besides the identify of the physical geographic conditions mentioned an essential difference is that considerable areas of the sandy rolling plain in the Danube—Tisza interfluve and of the loessal plain of Békés county gravitate toward the microregion of Szeged. Thus while the physical geographic conditions of the microregion of Szentes are roughly the same a very heterogeneous composition has evolved in its southern neighbor, since three physical geographic landscape units meet in the microregion of Szeged.

The differences in the physical geographic conditions are reflected in the structure of cultivation as well as in the structure of crops. Although the proportion of plowfields is similar on both regions near the Tisza and does not exceed the average proportion of plowfields in the Southern Plain, there is a considerable difference in other categories (vineyards, orchards, meadows and pastures). The proportion of irrigable areas is also different; it is much larger in the microregion of Szentes than in the region of Szeged. A difference in the crop structure is due to differences in the cultivation of vegetables. This proves that while the agriculture of the Szentes area belongs to one economic region, that of Szeged belongs to three different economic regions.

As in the case of the other microregions, these differences can be found in the composition of the agricultural raw materials as well as in the branches of the food industry. A well-developed diversified food industrial center has grown up in Szeged, while the food industry in Szentes and Csongrád is on a smaller scale and is different in profile.

The industrial development of the Szeged area differs in several respects from that of its northern neighbor. The more favorable geographic location of Szeged attracted some important branches of food and light industry (hemp, leather, wood industry) which formed the nucleus of later industrial development. Thus, owing to its extensive agricultural background and relatively favorable transport facilities, Szeged became the most impartant industrial center of the Southern Plain in the course of the industrial revolution of the last century and has kept its advantage to this day in spite of the fact that its development has not been uninterrupted and that owing to the proximity of the state border it has lost much of its attraction and its transport geographic situation has also changed.

The industrial development of Szeged in the last decade has certainly been rapid, and to the old branches of industry new ones have been added, e.g. crude oil production, cable factory, rubber factory, factory for prefabricated building sections, etc., which have transformed the town a light e.g. crude oil production, cable factory, rubber factory, factory for prefabricated building sections, etc., which have transformed the town form a light and food industrial center into a center with diversified anvanced industry. The most important feature that distinguishes the Szeged area from the neighboring microregions is the structure and scale of its industry.

The industrial development of Szentes and Csongrád differs from that of Szeged in its character and scale. Before the Liberation (of Hungary from fascist rule) the administrative function of Szentes was not combined with industrial function. The industrial development of these two towns actually began after the Liberation and has come to full bloom in the last decade. The branches of industry with high labor requirement dominate here; their heavy industry is much less developed than their light and food industry. The level of concentration of their industry is low, and this fact makes their situation similar to that of the Baja and Kiskunhalas areas.

Besides the similarity there is also an essential difference between the two regions of the Tisza as regards the effectiveness of the factors favoring the establishment of industry. In the microregion of Szeged all the factors favoring the establishment of industry are dominant. The conditions are worse only in Makó and Hódmezővásárhely, while in the Szentes area water and energy can be mentioned as dominant factors. A further important difference is that while Szeged offers favorable conditions to the cooperating branches of industry, the microregion of Szentes, like the microregions of Kiskunhalas and Baja,. has no such conditions.

There are also similar traits between the two microregions, e.g. nearly all the industrial centers have engaged the available free manpower and so their industry can be developed in the future only by intensive methods. Only Csongrád and Makó are different in this respect because these towns do not yet have any reserve manpower. Another common feature is that the problem of water supply can easily be solved in both regions, and in all probability this is going to be one of the most important industry-boosting factors in the future. As there is little manpower reserve but otherwise the conditions for the development of industry are favorable, it is advisable to give preference in the north and south along the Tisza just is in the region of Danube to the development of branches of industry of national importance instead of small capacity plants.

Such branches of industry are for example the chemical industry (water, skilled manpower, research institutes, raw materials, etc. are available), precision engineering, and some other branches of machine industry with high manpower requirement. The light and food industry can be developed in a centralized form first of all by modernization and expansion of the already existing capacity and not by the building of new factories.

The industrial and agricultural development of both regions will be greatly helped by the building of the third barrage of the Tisza.

The rate of industrial development in the two Tisza river regions in the last decade has been nearly identical. The index of the intensity of development in the Szeged area is 1.99, in the Szentes area 1.84. Thus the difference is unimportant, but the difference in the levels of development of the two areas must be taken into account. The index of the level of development of Szeged is 0.0598, that of the Szentes area is 0.0114. This determines also the degree of development. The Szentes region with its index of 0.532 is far below the average, while its southern neighbor with an index of 2.8 surpasses the average nearly threefold.

The differences in industrial development are reflected in the changes of the number of the population as well as in the movement of the population. In the Szeged region the number of the population has grown, the migration balance is positive, and the number of those engaged in agriculture is lowest here in the Southern Plain. On the other hand, the population of its southern neighbor has considerably decreased, its migration balance is negative, and the ratio of those engaged in agriculture is relatively high. Only in the ratio of urban inhabitants is there no essential difference. These facts are reflected in other connections, too, e.g. Szeged is surrounded by a broad agglomeration zone which is in contact with a strong inner zone where the population indexes are favorable. At the same time there are no agglomeration zones and inner zones around Szentes and Csongrád, as there are only a few settlements.

It follows logically from the foregoing that the transport and trade relations of the two regions are also entirely different; indeed it is interesting that the area of Szeged has close links with all the regions of the Southern Plain, though not with the region of Szentes. The Szeged region has stronger transport and production links with the regions of Baja county, the region of Kecskemét, and the region of Baja than with the neighboring regions of Szentes and Kiskunhalas.

The above-mentioned differences show that the two regions an the

Tisza follow their own lines of development and both have their own internal economicsocial life rhythms which is reflected in many things, among others in the mobility of the population.

4. The physical geographic conditions of the *microregion of Orosháza* are uniform and quite different from those of the neighboring western regions. The basis of the physical geographic landscape unit (the extent of which goes far beyond the boundaries of the microregion) is the loessial rolling plain of Békés which, as the alluvial deposit of the primeval Maros, was, from the point of view of surface development, mainly the result of the work of a river although considerable amounts of lake deposits were also formed. The material of the alluvial fan is mostly medium — and coarse-graines sand (pebbly sand), but near the surface and among the more porous sediments there are often water-impermeable clay layers. Near the surface the thickness of the coarser-grained sediment in the SE parts is about 8—10 m, in the WNW parts only 1—2. The top formation is usually loess. Typical loess occurs only in traces. Along the former river beds and in their neighborhood meadow clay, clayey silt and washed loess can be bound, i.e. the rather inhomogeneous sediment near the surface has produced differentiated soils.

The are the following: the central part of *the alluvial fan of the Maros* (the area between Orosháza, Dombegyháza, Elek, and Csorvás). The sediment near the surface is mostly sand and sandy loess. Due to stronger influence of the climatic and hydrographic conditions, meadow chernozems have formed here with dark brown, medium thick, and deep humus layers.

The area between the western wing of the western wing of the alluvial fan of the Maros (the plain of Csongrád), Battonya, Orosháza, Mindszent and the area between the Tisza and the Maros can be regarded as one subregion. Its surface, which slopes gently toward the valley of the Tisza, is covered by an infusion loess layer which becomes thicker from east to west. Clay and silt layers covered by infusion loess commonly occur in this territory. On the loessial sediment lime-covered chernozem soils formed besides the lowerlying subsoil water with frequent alkalination.

The northeastern wing of the alluvial fan (the plain of Békés) lies between Békéscsaba, Gyoma and Csorvás. It is a monotonous table covered with infusion loess. At the surface on the thick loessial sediment there are chernozem soils and in the direction of the Körös river valley limy chernozem and meadow chernozem soils.

The physical geographic conditions of the region are favorable for raising corn, wheat, sugar beets, hemp and open-field vegetables as well as for creating the provender basis necessary for hog and poultry raising. Accordingly, the ratio of plawfields is the highest in this region in the Southern Plain. Besides this it is characteristic that the ratios of orchards, meadows, and pastures are very small in comparison. The crop structure of the region, like the branches of cultivation, differs considerably from that of the other regions as the ratio of wheat and industrial plants far exceeds the average of the regions.

Of course the profile of the agriculture is reflected in the structure of food industrial raw materials. While for instance wine, fruit, and canned products have prime importance in the Danube—Tisza interfluve, in the Orosháza, region the most important economic activities are the buying up of poultry and industrial plants, and the cultivation of open-field vegetables comes only after these in importance. The food industry of the region is milling, poultry processing, and sugar industry.

The industrial development of the region, aside from some branches of food industry, actually began after the Liberation and is going on rapidly in our days. Unlike what has happened in the other regions, the value of the industrial fixed assets and the utilization of energy have increased with incredible rapidity and it is due to this fact that the index of development intensity in the region is 4.38, the highest in the Southern Plain, and twice as high as the average. Similarly, it is due to this fact that the Orosháza region holds third place in the rank scale of the micro-regions of the Southern Plain in respect of level of development (0.0178) and ratio of development (0.831).

The rapid industrial development of the Orosháza region is not reflected in the changes of the number of population or other indexes characterizing the population. Here among the regions has the population decrease been the sharpest.

Population devrease due to out-migration has also been greatest here. The ratio of those engaged in agriculture, though considerably reduced now, still far exceeds the average of the Southern Plain (53.2). The ratio of urban inhabitants is the lowest here among the regions.

Out-migration of the population has indeed decreased considerably in recent years, yet, even so it remains significant. The explanation for this is that the development of industry parctically concerns only one part of the region, Orosháza, while the district of Mezőkovácsháza still has important manpower reserves. An explanation for the contrast between the favorable development of industry and the unfavorable trend of the population indexes is also the structure of the local (regional) industry; the development of crude oil and glassware production (which require large investments and expensive fixed assets) alone cause but little changes in population.

The conditions Orosháza for the establishment of industry are favorable: of the seven indexes three are dominant factors. Only the scarcity of water is a drawback. In the district of Mezőkovácsháza the manpower reserve and the highly developed agriculture favor the growth of the local industry.

The structure of the local industry, its rate of development, and the profile of the agriculture are characteristic features which distinguish the Orosháza region from the neighboring regions. The difference is apparent also in the economic and social processes taking place within the microregion.

5. The physical geographic conditions of the *Békéscsaba region* are not uniform; the region consists of two physical geographic regional

units. The southern part of the region is different, but its features resemble in many respects the physical geographic conditions of the Orosháza region described above. A large part of the northern section of the area lies in the region of the Körös rivers which is characterized chiefly by the fact that it was formed, like the Tisza river valley, during the Pleistocene and the Holocene periods. The surface is covered all over by young sediments but on the higher lying areas there are formations made by the rivers. It is generally believed that the region of the Körös and the Berettyó was the large water- and deposit-collecting area and erosion base of the Trans-Tisza region. Thus the surface of the region of the Berettyó and the Körös is almost interely made up of Holocene alluvial (fluvial) deposits. Transported silty loess, silty clay, and in the deepest depressions turf and kotu (a special Kind of turf) were formed. The youngest formations, the alluvial soils (sand, silt, silty clay) in a broad band along the Körös, are areas suitable for cultivation with modern methods of irrigation. The loessial deposits are covered by so-called loam soil in the higher lying parts. Younger Holocene filling covers nearly all of the area and so older soils remain partially buried near the surface. In such a soil structure the water balance and the depth of humus are more favorable.

The work of flood prevention and river control in the last century brought about perceptible changes in the appearance of the country and at the same time had an important influence on the soilforming processes. As it is well known, not only passive water economy was used but by the end of the last century also one of the most advanced methods of cultivation by irrigation in this country. The effect of the feoods and stagnant waters before the floodpreventing system was built still remain to a great extent in the soil structures. Rusting of the subsoil, gleyey structure, and alkalination are common in meadow soils. In our days soil amelioration is being carried out by properly chosen agrotechnique and modern methods of irrigation.

The physical geographic conditions here are favorable for the cultivation of corn, wheat and some industrial plants, but the average yields are below those of Békés country.

The agriculture of the microregion of Békéscsaba roughly agrees with that of the Orosháza area and the problems of development are also essentially the same in the two areas.

In the collection purchase of raw materials meat, poultry, and canning industrial raw materials are represented by large quotas. The Békéscsaba region has a diversified and well developed food industry. Therefore its purchasing area extends also into the district of Mezőkovácsháza.

Based on the agriculture and the plentiful manpower available the industrial development of the region began in the second half of the last century and has been going on ever since with varying intensity (between the two world wars it remained at one level). With an urban background in Békéscsaba and Gyula, much more advanced and diversified industry could develop than in Orosháza. These towns possess several branches of industry of national importance, for instance meat, milling, canning, textiles, and knitwear.

The factors favoring the establishment of industry can be found with varying effectivity in the territory of the region. Five factors (manpower, education, transportation, urban background, and energy) out of seven are dominant in Békéscsaba. On the basis of these factors a wide scale of branches of industry can be established here, e.g. laborintensive branches of machine industry, building material industry, wood, textile, and clothing industry, and many branches of food industry. Only ensuring an adequate water supply is a problem.

The Békéscsaba region has several settlements where industry with high efficacity can be developed. These settlements are: Gyula, Szarvas, Endrőd, Gyoma, Szeghalom, Békés, Vésztő. All of these settlements have considerable manpower resources besides relatively good transportation and energy conditions. Ensuring the water supply is a problem in all of them.

As regards the perspectives of the development of industry there is an essential difference between the northern and the southern parts of the region.

The southern part of the region has a highly developed infrastructure, diversified industry and still considerable manpower reserves. On this basis first of all laborintensive factories requiring cooperation, and as the territorial concentration of manpower is high, nationally important factories can be established here, while in the northern part of the region there is only a weak urban background, the manpower is poorly trained, territorially decentralized, difficult to concentrate and therefore it is practical to establish here laborintensive factories mainly producing machine parts.

A considerable area of agricultural character and with little industry belongs to the Békéscsaba region. This is the explanation why the level of development of the industry here is essentially the same as in the Orosháza region (0.0172). Also the index of the rate of development is scarcely higher (0.831) and does not reach the average of the Southern Plain. The index of the intensity of development is surprisingly low (1.8) and the region differs markedly from the Orosháza region in this respect, too. The slower rate of industrial development explains the fact that while the Békéscsaba region held second place among the microregions of the Southern Plain in 1964, in 1970 it was in the fourth place. The population indexes of the region can be said to be generally unfavorable. The decrease of the number of population between 1960 and 1970 (— 3,2' was much more considerable than in the previous decade. On the other hand, the loss by out-migration somewhat decreased but could even so be said to be very high (5.6 per cent between 1960 and 1970). The ratio of urban inhabitants grew considerably in 1972 (from 33 per cent to 43 per cent) owing to the fact that Szeghalom and Békés were incorporated as towns.

Békéscsaba and Gyula play the role of economic centers in the region; the two centers mutually strengthen each other's attraction but even so their influence is rather weak in the northern part of the area. Curiously enough Szeghalom begins to play the role of an economic center here. There are a number of indications (transportation of agricultural products, growth of the number of the population, the development of industry, etc.) that a new economic microregion with Szeghalom as its center is developing in the north of Békés county. The area mentioned possesses all the qualities that, as in the case of the Orosháza region, make it later possible that distinctive traits develop.

The traffic and transport connections of the region with the Orosháza and the Szeged regions are understandably strong, but with the other microregions of the Southern Plain rather loose. More ties connect the region to Szolnok county than to the western part of the Southern Plain.

By the definition and short characterization of the microregions of the Southern Plain we have tried to prove that the territorial units mentioned differ from each other in many economic features; each has a distinctive structure, and all differ also as regards their possibilities and trends of development.

THE OPEN-MARKET ATTRACTION SPHERES OF THE TOWNS OF THE SOUTHERN PART OF THE GREAT HUNGARIAN PLAIN

by

DR. I. PÉNZES

An important measure of the attraction of towns and their influence on the neighboring settlements is the daily open-market trade. The author feels that with the help of data of this trade it is possible to assess reliably which are the settlements that are so organized as to provide the daily supply of the towns and which are those that owing to greater distances, bad road conditions, or the attraction of other settlements etc., play such a role only intermittently. In order to determine the attraction spheres of the markets the author has collected pertinent data in the past few years (1968—71).

The following questions were examined in the survey:

a) Where did the commodity come from?

b) What means of transport was used by the seller?

c) What sort of commodity and how much of it did the seller bring to the market?

d) Was the commodity household farm or cooperative farm product?

e) At what price did the seller sell each particular commodity?

The days for survey were chosen on the basis of experience and in agreement with the advice of the councils of the areas involved. At least two market days a week are characteristic of each settlement having a market of its own. Practical experience and the author's data prove that the territorial influence of the market is best shown by the main market days of each center; consequently in each place the data of the main market day were collected.

Of the data collected, the number of local traders and their territorial distribution proved suitable for determining the attraction spheres of the markets. Mapping and evaluation of data led to the following conclusions:

1. In the southern Part of the Great Hungarian Plain (henceforth Southern Plain) it is the town of Szeged which has the most important market supply zone. Szeged, as the regional center of the Southern Plain, attracts the majority of the local traders and the bulk of the marketed commodities from its territorially important integrant microsector.

a) To the inner market supply zone of Szeged belong Röszke, Mórahalom, Zákányszék, Bordány, Forráskút, Zsombó, Balástya, Szatymaz, Sándorfalva, and Deszk; similarly Tápé, Algyő, Szőreg, and Gyálarét, which were attached to Szeged earlier this year, and Kiskundorozsma, which has a different character and role.

a/a. Szőreg, Tápé, Gyálarét and Algyő clearly belong to the inner supply zone of Szeged. Their surplus products, like those of Újszeged, are sold exclusively in Szeged.

b/b. The role of Domaszék differs from that of the afore-mentioned villages in that some low percentage of its surplus products are sold in- Kiskundorozsma. The ratio of local traders is 48:13 in favor of Szeged. Otherwise, from the point of view of its market supplying role this settlement also belongs to the inner supply zone of Szeged.

c/c. Kiskundorozsma, owing to its important market with 3 market days a week and resulting from its former administrational status, attracts part of the local traders from its former village outskirts. But while earlier it took only a small number of local traders away from Szeged owing to its lower interior demand, as a result of changes in the last 10 years the ratio now is 43:12 in favor of Kiskundorozsma against Szeged. It has considerable attraction for other settlements too (Forráskút 10:9, Üllés 6:3, and Bordány as against Szeged. Thus Kiskundorozsma occupies a special place in the immediate market attraction sphere of Szeged.

b) *The so-called secondary or outer zone of Szeged* is made up of Ásotthalom, Rúzsa, Újszentiván, Tiszasziget, Kübekháza, Ferencszállás, Klárafalva, and partly Kiszombor. These settlements were put in this category partly on account of the smaller number of local traders and partly on account of their agricultural structure which is characteristic of the outer supply zone. With the exception of Kiszombor they gravitate exclusively toward Szeged on the basis of daily market trade and state purchase.

c) In the case of *Szeged and Kiskundorozsma,* the lower level of self-sufficieny and the variety of commodities suggest that specialization has progressed in the agriculture of these setllements (production of certain commodities on a larger scale has become characteristic, while the production of other commodities has been transferred to the outer zone); again, these data point to the autarchic (polycultural) character of the agriculture. Many kinds of commodities are produced but only small quantities are marketed; therefore the missing articles are brought to the markets of Szeged and Kiskundorozsma from the outer zone. Similar tendencies seem to obtain for example in the case of Kiskunmajsa, too.

2. In the case the towns of *Makó and Hódmezővásárhely* the high level of internal supply is indicative of varied agricultural production. In the case of some branches of production there is specialization, but a high level of self-sufficieny is characteristic of these towns with wide outskirts. The smaller characteristic external supply derives from the production structure of the nearby settlements, which agrees to a great extent with that of these towns; consequently the goods marketed sell at a low price or may not sell at all. Therefore the settlements of the neighborhood sell their surplus products to the largescale purchasing agencies as thus they can sell them at nearly the same price. In the

market of the towns those neighboring settlements are represented by the largest number of local traders which can send products that are scarcely or not at all produced on the outskirst of these towns. In the case of Hódmezővásárhely for instance Mártély supplies apples while Makó supplies onions, parsley and carrots.

a) Mártély and Székkutas clearly constitute the *inner supply zone of Hódmezővásárhely*. The local farmers of Mártély can sell their products exclusively in the markets of Hódmezővásárhely, while the majority of the local farmers of Székkutas sell their goods in Hódmezővásárhely and an insignificant percentage of them sell their goods also in the markets of Orosháza.

b) *The outer market supply zone of Hódmezővásárhely* is essentially limited to two settlements: Mindszent and Makó. Car-owning farmers of Maroslele and remoter settlements also occasionally appear.

c) Car-owning farmers of *Makó and its neighborhood* sell their goods in the daily markets of the larger settlements of the Southern Plain and in the open markets of the South-eastern Plain on account of the important onion, greens, and carrot production in those parts. It is due to this traditional specialization of Makó and its neighborhood that Makó is part of the supply zone of both Szeged and Hódmezővásárhely.

d) *The inner supply zone of Makó* — owing to its high level of self-sufficiency — is, like that of Hódmezővásárhely, of small extent. Its settlements are: Magyarcsanád, Maroslele. Apátfalva which is also part of the outer zone of Mezőhegyes, partly belongs here, and so does Kiszombor, which on the other hand is one of the outer suppliers of Szeged.

e) The markets of *Makó* have no territorially definable outer market supply zone. Occassionally a few marketers from the neighboring villages, Óföldeák, Királyhegyes, Kövegy, Nagylak and Csanádpalota sell their goods in its markets.

3. The market attraction of the towns of *Szentes* and *Csongrád* shows the characteristic pattern of areas with two centers. The supply zone of Szentes has largely developed in the areas east of the river Tisza, whereas the supply zone of Csongrád ha developed in the areas near the Tisza between this river and the Danube.

a) *The inner supply zone of Szentes* is made up of the villages of Szegvár and Mindszent.

b) The inner market zone of Csongrád comprises Felgyő and Csanytelek.

c) *The secondary market supply zone of Szentes* is composed of the villages of Derekegyháza, Nagymágocs, Magyartés and Felgyő and the town of Csongrád.

d) *The secondary market supply zone of the town of Csongrád* comprises the villages of Tömörkény and Magyartés and the town of Szentes.

e) The market supply zones of both market centers Szentes and Csongrád are of small extent. This suggests first of all a high level of the internal supply, the varied structure of production, but also a narrow specialization, most often on just one branch of production, and thirdly an identical or nearly identical production structure of the nearby settlements or supply zone.

f) The small market supply zone characterizes well the economic role, level of industrialization and urbanization of the centers, the distribution of the population according to professions i.e. all the factors that determine the outward structure of agricultural production.

4. In the market attraction of the twin centers *Békéscsaba and Gyula* the leading role of Békéscsaba clearly appears.

a) To *the internal market supply zone of Békéscsaba* belong Békés, Murony, Doboz, Szabadkígyós, Újkígyós, Gerendás, Kétsoprony, and Gyula.

b) *The inner supply zone of the town of Gyula* is limited to the village of Gyulavári.

c) *The outer market supply zone of Békéscsaba* is made up of Sarkad, Nagykamarás, Pusztaottlaka, Kondoros, Telekgerendás, and Orosháza.

d) To *the outer market supply zone of Gyula* belong Doboz, Gerla, Sarkad, Kötegyán, Kétegyháza and Elek.

e) The market supply zones of the two towns clearly show their roles. The more urban role of Békéscsaba manifests itself in the fact that its inner market supply zone is far more important than that of Gyula but also in the fact that the market attraction of Békéscsaba in the secondary attraction zone of Gyula is usually more powerful than the market attraction of Gyula.

5. *Orosháza* belongs among the largely self-supplying centers. The development of its industry in recent years and the acceleration of its urbanization exert a growing influence on the production structure of its neighborhood.

a) Its *inner supply zone* consists of only one village, Kardoskút.

b) Its *secondary* or outer *supply zone* is more considerable. The increasing influence of the town in its neighborhood manifests itself in the reorganization of its supply zones. To its outer supply zone belong Csanádapáca, Székkutas, and Csorvás.

6. Tótkomlós is a self-supplying market center; the neighboring villages provide scarcely one third of its market supply, which proves the weakness of its influence on its neighborhood.

7. The southern and southeastern areas of Békés county are a part of the county with several centers. Mezőhegyes, Battonya, Mezőkovácsháza (the seat of the District Office) are also market centers.

8. In these areas the market supply of *Mezőhegyes* is the most considerable. Its supply zones can also be delineated.

a) *The inner supply zone of Mezőhegyes* is made up of Pitvaros and Mezőkovácsháza.

b) *Its outer supply zone* is relatively extensive; its villages are Nagyér, Ambrózfalva, Csanádalberti, Csanádpalota, Kövegy, Makó, Kevermes, Orosháza, Végegyháza, Nagybánhegyes, and Tótkomlós.

9. *Battonya is self-supplying without an inner supply zone.* Its outer

supply zone extends to remoter areas and the nearest market centers. Its supply zone is Medgyesbodzás, Kunágota, and Mezőhegyes.

10. *Mezőkovácsháza is self-supplying.* Its daily market zones have not developed yet. Of the three settlements this has the smallest role in spite of the fact that it is a district seat. Among these settlements *Mezőhegyes* is taking on more and more urban functions owing to the high specialization of its agriculture. In consequence of the growth of its open markets it may become an important market center with well-definable supply zones.

11. *The market attraction of Kecskemét and that of Kiskunfélegyháza* are very similar. Both settlements exert a great influence on relatively remote villages. The difference between the two settlements manifests itself in the size of their inner zones in favor of Kecskemét.

a) To *the inner supply zone of Kecskemét* belong Ballószög, Helvécia, Városföld, and Jakabszállás.

b) *The outer supply zone of Kecskemét* comprises Lakitelek, Cserkeszőlő, Alpár, Kunszállás, Bugac, Fülöpháza, Hetényegyháza, Zöldhalom, and Lajosmizse.

c) *The inner market supply zone of Kiskunfélegyháza* comprises only Pálmonostora and Szank, so that Szank belongs also to the inner supply zone of Kiskunmajsa.

d) *The outer supply zone of Kiskunfélegyháza* is sizable. On some settlements Kiskunfélegyháza exerts an influence together with Kecskemét. The villages belonging to its outer supply zone are Gátér, Felgyő, Alpár, Pusztaszer, Csengele, Petőfiszállás, Jászszentlászló, Bugac, Kunszállás, and Zöldhalom.

12. *Kiskunhalas* and *Kiskunmajsa* are market centers. Data were collected only is Kiskunmajsa. On the basis of these data the following can be stated:

a) *Kiskunmajsa is* a *self-supplying* settlements with a market supply zone. *Its inner supply zone* has already developed. Kömpöc and Csólyospálos belong here.

b) *The outer supply zone of Kiskunmajsa* comprises Csengele, Kiskunhalas, Forráskút and Tázlár.

c) The market attraction of Kiskunmajsa provides an objective basis to the delineation of the western boundary of the integrant microzone of Szeged, too.

13. The independent role of *Baja* is clear not only in respect of other factors of attraction but also in respect of market attraction. The independent market zones of Baja are scarcely disturbed as there are no major settlements nearby or farther away. Bácsalmás, Mélykút, Bátaszék, etc. are too small settlements to affect the market attraction sphere of Baja. Kiskunhalas, Kalocsa and Mohács, on the other hand, are so far that their market attraction cannot be felt at Baja.

a) *The inner market supply zone of Baja* comprises Bácsbokod, Érsekcsanád, Sükösd, Bátmonostor, Szeremle, Nagybaracska, Dávod, and Vaskút.

b) *The outer market supply zone of Baja* comprises the villages of

Alsónyék, Báta, Dunaszekcső, Csátalja, Hercegszántó, Bácsbokod, Felsőszentiván, Borota, and Dusnok (Figs. 1—2).

14. The assessment of the market centers of the Southern Plain is not complete. It would be necessary to assess also the markets of Kalocsa, Kiskőrös, Dunavecse, Kunszentmiklós, Kiskunhalas, Bácsalmás, Kistelek, Szarvas, Vésztő, etc., and the seasonal changes in the markets.

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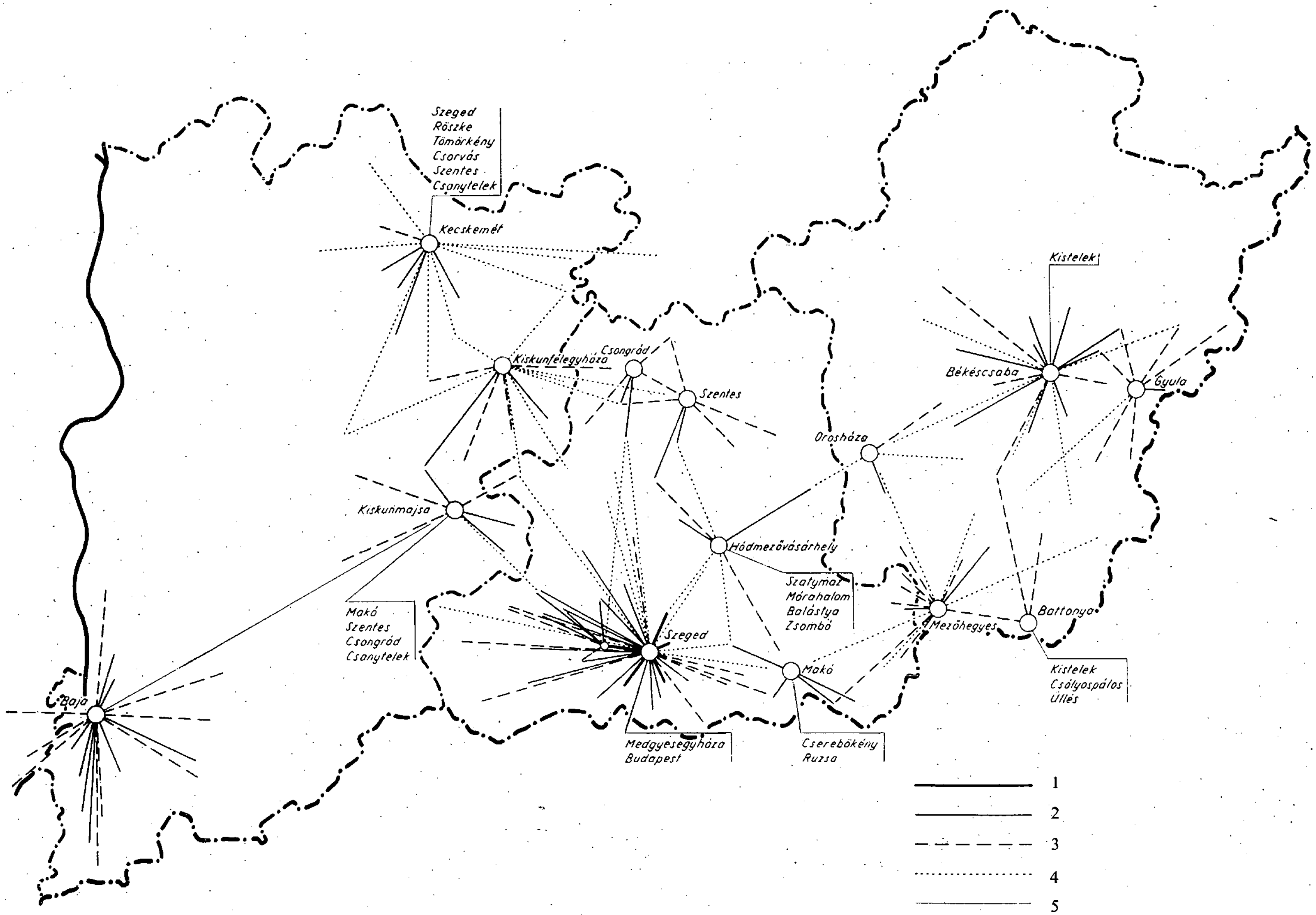
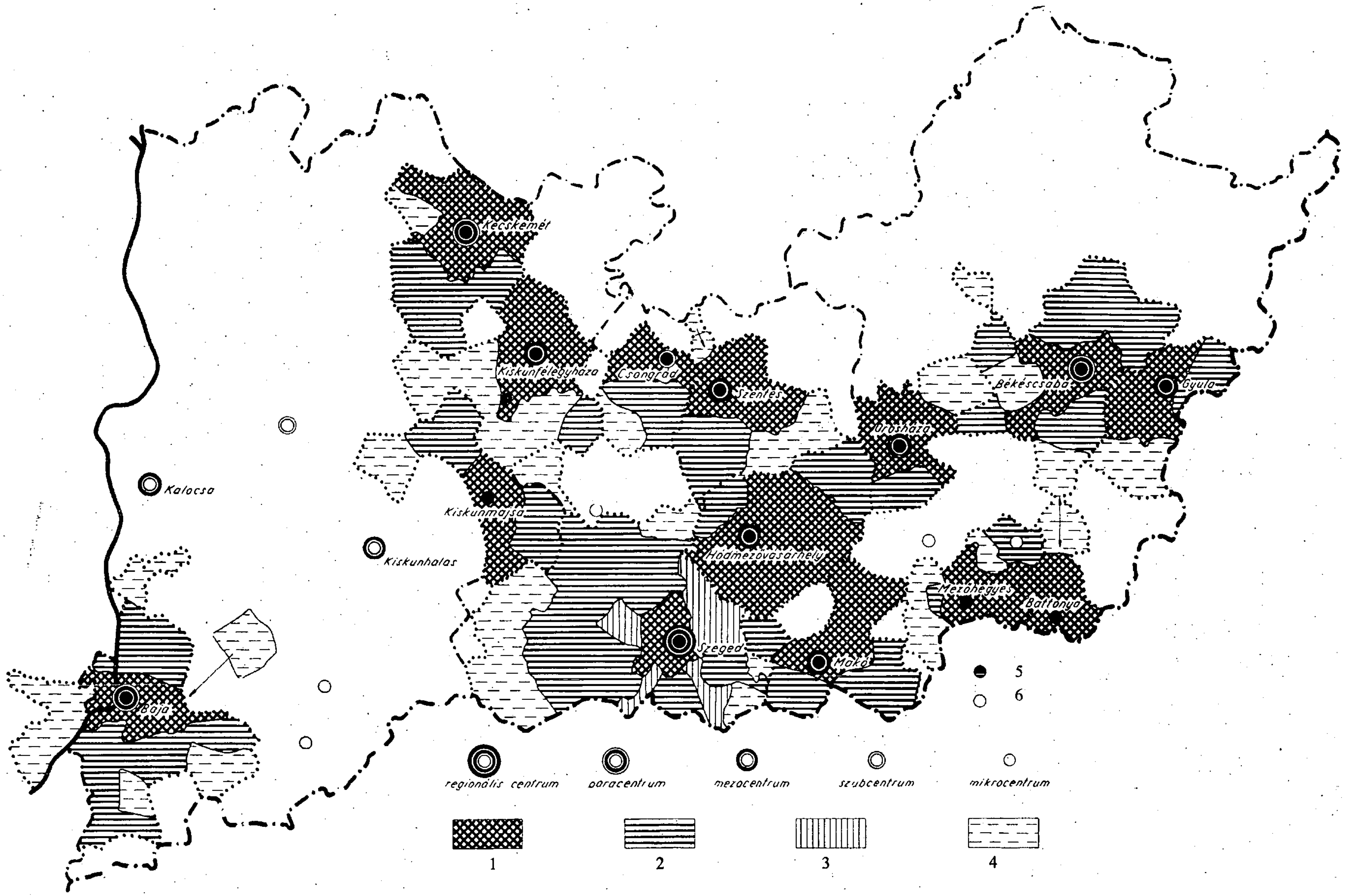


1. Open market attraction intensity of the centers of the Southern Plain.
   1. Agglomeration belt
   2. Primary attraction
   3. Secondary attraction
   4. Tertiary attraction
   5. Occasional attraction



2. Attraction spheres of the open market centers of the Southern Plain
- I. Inner zone
  1. Area belonging to market center
  2. Primarily attracted area
  3. Agglomeration belt with markets similar to those of the center
- II. Secondary zone
  4. Secondarily attracted area, outer market supply zone
  5. Assessed market center
  6. Unassessed market center

THE ROLE OF THE HIERARCHIC LEVEL IN THE OCCUPATIONAL REORGANIZATION OF THE WAGE EARNERS OF THE CENTERS OF THE SOUTHERN PART OF THE GREAT HUNGARIAN PLAIN (1960—1970)

by

DR. J. TÓTH

Industrialization, vigorous expansion of production, and growth of the importance of the tertiary sector alter the occupation structure of the population and reorganize the most important force of production, the working population. For the majority of the population this reorganization means not only a change of occupation but also a change of residence. The new structure of production creates a new spatial structure and leads to a new territorial distribution of the workforce.

Industry and the tertiary sector, compared with the agriculture, make a much higher concentration of the workplaces necessary. Thus the occupational regrouping of the population means also its territorial concentration.

An ever growing proportion of non-agricultural workplaces can be found at settlements performing higher functions for their surrounding areas. Thus they play a special role in the occupational reorganization and territorial concentration of the population.

I. Purpose and method of the present paper

The purpose of the present study is to report on the role of the centers of the southern part of the Great Hungarian Plain (hereafter the Southern Plain) and their hierarchic grades in the process of occupational regrouping.

The development of the occupational composition or structure of occupations of all wage-earners (active and inactive together) between 1960 and 1970 has been used as a basis.

As regards the areas of the centers and their hierarchic grades, we have relied on the last summary of our investigations carried out during several years (J. Tóth, 1972). According to this one regional center (Szeged), three paracenters (Kecskemét, Békéscsaba, Baja), eight mesocenters (Kalocsa, Kiskunhalas, Kiskunfélegyháza, Szentes, Hódmezővásárhely, Makó, Orosháza, Gyula), six subcenters (Kiskőrös, Csongrád, Szarvas, Gyoma, Békés, Szeghalom), and fourteen microcenters (Mezőkovácsháza, Mezőhegyes, Medgyesegyháza, Tótkomlós, Battonya, Kunszentmiklós, Dunavecse, Solt, Jánoshalma, Bácsalmás, Kiskunmajsa, Kistelek, Mezőberény, Sarkad) can be distinguished in the Southern Plain.

The quantitative definition of the occupational regrouping proportional also with the changes in the number of all wage earners can be expressed by the C index according to the following formula:

$$C = \frac{X_1 \cdot Y_2}{X_2 \cdot Y_1}, \text{ where}$$

X_1=number of all wage earners in 1960,
X_2=number of all wage earners in 1970,
Y_1=number of wage earners in the branch examined in 1960,
Y_2=number of wage earners in the branch examined in 1970.

II. **Results**

1. *Changes in the number of all wage earners*

The number and ratios of all wage earners between 1960 and 1970 with regard to the centers and other settlements of the Southern Plain developed so that the development clearly indicates the growing importance of the centers and within their group the growing importance of the higher hierarchic grades.

The number of wage earners in the region grew by 90.000 during the ten years examined. More than nine-tenthes of the growth fell to the centers, and this meant a 21.4% growth as compared with the number in 1960. The number of the wage earners of the other settlements grew only by 1.3%. (As the direction of the change in the total number of population in the two groups of settlements is different, the difference appearing in the value of the C indexes is smaller, only 0.04.) The ratio of the change, in the settlements with center role, lessens from the higher hierarchic grades to the lower grades. It is remarkable that there is hardly any difference between the ratio of Szeged and that of the paracenters.

TABLE 1
Changes in the number and ratios of wage earners in the center settlements of the Southern Plain (1960—1970)

	Wage earners (1960)		Change (1960—1969)		„C" index	Wage earners (1970)	
	number	ratio %	persons	%		number	ratio %
Reg. center	59794	60,4	20692	34,61	1,12	80486	68,0
Paracenters	81414	55,5	27643	33,95	1,16	109057	64,9
Mesocenters	133592	54,4	25503	19,09	1,15	159095	62,6
Subcenters	49880	51,9	6958	13,95	1,15	56838	59,7
Microcenters	70055	52,6	3795	5,42	1,11	73850	58,8
Total of centers	394735	54,8	84591	21,43	1,15	479326	62,9
Other settlements	406911	53,0	5452	1,34	1,11	412363	58,9
Total of Southern Plain	801646	53,8	90043	11,23	1,13	891689	61,0

Owing to the arrangement of the ratios of change according to the hierarchic grades, by 1970 the order of magnitude of the grades, which was still defective in the basic years, is established corresponding to the ratio of all wage earners of the centers as compared with the total population. The ratio of wage earners of the subcenters is also above the average of the noncentral-like settlements, while the ratio of the microcenters is only minimally below the average (Table 1).

2. *Changes in the number of agricultural wage earners*

The number of the agricultural wage earners of the region decreased by more than 55.000 in the decade examined. Their number in 1970 was only 44.1% as against 55.9% in 1960.

The decrease took place in a differentiated way. It was less in the centers (8.7%) than in the other settlements (14.1%); thus the situation was that at the end of the decade a larger ratio of the agricultural wage earners remained in the center settlements than in 1960. Yet in the centers with rapidly growing populations of wage earners the value of the C index expressing the relative weight change of the wage earners in the particular branch of economy was smaller (0.75) than in the other settlements (0.85).

The order according to the rate of change and the value of the C index is not identical with the hierarchic order. The centers representing identical hierarchic grades function in different type areas, which have distinctive traditions, weights, and especially present possibilities, and their values are merged in the average. In Szeged the number of agricultural wage earners increased by more than 2.500 persons owing to the favorable selling and income conditions (market conditions) of the dyna-

TABLE 2.

Changes in the number and ratios of agricultural wage earners in the center settlements of the Southern Plain (1960—1970)

	Agricultural wage earners (1960)		Change (1960—1969)		„C" index	Agricultural wage earners (1970)	
	number	ratio %	persons	%		number	ratio %
Reg. center	3904	6,5	2511	64,32	1,23	6415	8,0
Paracenters	18364	22,6	—804	—4,38	0,71	17560	16,1
Mesocenters	52073	39,0	—3857	—7,41	0,77	48216	30,3
Subcenters	26222	52,6	—1379	—5,26	0,83	24843	43,7
Microcenters	43086	61,5	—8958	—20,79	0,75	34128	46,2
Total of centers	143649	36,4	—12487	—8,69	0,75	131162	27,4
Other settlements	304835	74,9	—43047	—14,12	0,85	261788	63,5
Total of Southern Plain	448484	55,9	—55534	—12,38	0,78	392950	44,1

mically developing city. The increase was larger in the number of all wage earners; the value of C was 1.25. Thus the ratio of agricultural wage earners reached 8,0% by 1970 as against 6.5% in 1960.

The ratios of the agricultural wage earners to the number of all wage earners corresponded to the hierarchic grades of the centers already at the beginning of the decade. The same relationship was still more clearly apparent in 1970 although owing to slow regrouping of the wage earners of the subcenters the difference between the micro and subcenters had become smaller (Table 2.).

3. *Changes in the number of wage earners in the industries and the building trade (industrial wage earners)*

The greatest changes in the decade examined took place in the number and ratios of the industrial wage earners. The number of the industrial wage earners grew by more than 127.000, i.e. 83.1% in the region so that the rate of growth of the centers remained somewhat below that of the other settlements (82.7 and 84.1% respectively). The rate of change according to the hierarchic grades is corresponding: it grows from the regional center toward to microcenters; the subcenters constitute an

TABLE 3.

Changes in the number and ratio of industrial and building workers (wage earners) at the center settlements of the Southern Plain (1960—1970)

	Industrial and building workers (1960)		Change (1960—1969)		„C" index	Industrial and building workers (1970)	
	number	ratio %	persons	%		number	ratio %
Reg. center	22660	37,9	16352	72,16	1,27	39012	48,5
Paracenters	27443	33,7	23381	85,20	1,38	50824	46,6
Mesocenters	33786	25,3	29348	86,86	1,56	63134	39,7
Subcenters	10745	21,5	7447	69,31	1,48	18192	32,0
Microcenters	11988	17,1	11604	96,80	1,86	23592	31,9
Total of centers	106622	27,0	88132	82,66	1,50	194754	40,6
Other settlements	46808	11,5	39357	84,08	1,81	86165	20,9
Total of Southern Plain	153430	19,1	127489	83,09	1,65	280919	31,5

exception. The situation is similar according to the C index values expressing the relative changes in the ratio of those engaged in this branch of economy: the series growing toward the microcenters is broken by the subcenters which show little dynamic regrouping. In the row of the ratios of industrial wage earners to all wage earners, which became established according to the hierarchic grades of the centers already in 1960, an important change in tendency not affecting the order took place: the difference between the paracenters and Szeged as well as the difference between the sub and microcenters became less. Unlike the situation in 1960, the ratio of the industrial wage earners of the microcenters was above the average of the Southern Plain by 1970 (Table 3).

4. *Changes in the number of other wage earners*

The number of wage earners in other occupations grow by only 9.1%, during the 1960's. The increase was less in the centers (6.2%) than in the other settlements (16.5%). As a result of a faster rate of growth in the number of all wage earners, the C index was less than one (0.87) at the settlements with center functions and 1.15 at the other settlements. In all grades of centers the number of other wage earners grew; most considerably in the paracenters (14.23%), least in the mesocenters (0.02%). The value of the C index varies according to the hierarchic grades of the centers, excepting the mesocenters, so that it exceeds one only in the case of the microcenters. The ratio of other wage earners to all wage earners is highest is Szeged and decreases according to the grades of hierarchy. By 1970 the ratio of the subcenters had sunk below the average of the Southern Plain and had come nearer to that of the microcenters (Table 4).

5. *The concentration of wage earners according to the hierarchic grades of the settlements*

The centers play a much greater role in the regrouping of the wage earners of the region than could be excepted from the ratio of their population to the total population of the Southern Plain.

TABLE 4.

Changes in the number and ratio of other wage earners at the center settlements of the Southern Plain (1960—1970)

	Other wage earners (1960)		Change (1960—1969)		„C" index	Other wage earners (1970)	
	number	ratio %	persons	%		number	ratio %
Reg. center	33230	55,6	1829	5,50	0,78	35059	43,5
Paracenters	35607	43,7	5066	14,23	0,85	40673	37,3
Mesocenters	47733	35,7	12	0,02	0,84	47745	30,0
Subcenters	12913	25,9	890	6,89	0,94	13803	24,3
Microcenters	14981	21,4	1149	7,67	1,02	15130	21,9
Total of centers	144464	36,6	8946	6,19	0,87	153410	32,0
Other settlements	55268	13,6	9142	16,54	1,15	64410	15,6
Total of Southern Plain	199732	25,0	18088	9,06	0,98	217820	24,4

In 1970 the centers held 52.1% of the population of the region. Of all wage earners they held 53.8%, of the industrial and building workers 69.3%, and of other wage earners 70.4%. Thus the concentration of the active population (and of those employed in the other two branches of economy, which are important from the point of view of the regrouping), was greater than that of the total population. Owing, to the accelerating and greater dynamism of the regrouping of the population of the other settlements (which in the majority of the cases was due just to the influence of the centers and to the low basic values where the rates are concerned), the concentration of industrial and building workers and other wage earners decreased on the whole as compared with the figures of 1960.

From the point of view of the hierarchic grades the centers can be classified into:

a) *Regional center:*

The degree of concentration of all wage earners and workers in the two branches examined (agriculture and industry) was greatest here. The concentration of other wage earners, though decreased as compared with the situation at the beginning of the decade, was remarkable: it was nearly double the ratio to the population:

b) *Paracenters:*

In accordance with their place in the hierarchy the degree of concentration was high and both as regards the number of wage earners and the two branches of economy increased in the decade examined. Although to a much lesser extent than in the case of Szeged, the concentration of those employed in the other branches of economy exceeded that of the industrial

c) *Mesocenters:*

The degree of concentration was much less here than in the paracenters; considering all wage earners and the industrial and building workers it grew, considering the other wage earners it diminished during the decade. The concentration of those engaged in other branches of the economy was smaller by 1970 than that of the industrial and building workers.

d) *Subcenters:*

In the case of the population number a greater concentration was not reached even in 1960 uniformly and by 1970 it was not manifested in any component examined by us. The contingent of wage earners grew faster than the ratio to the total population but even in 1970 it could only approach it. The ratio of industrial and building workers in 1960 was still slightly greater than the ratio of population, but by 1970 it had fallen below that. The backwardness of the subcenters in industrialization was remarkable.

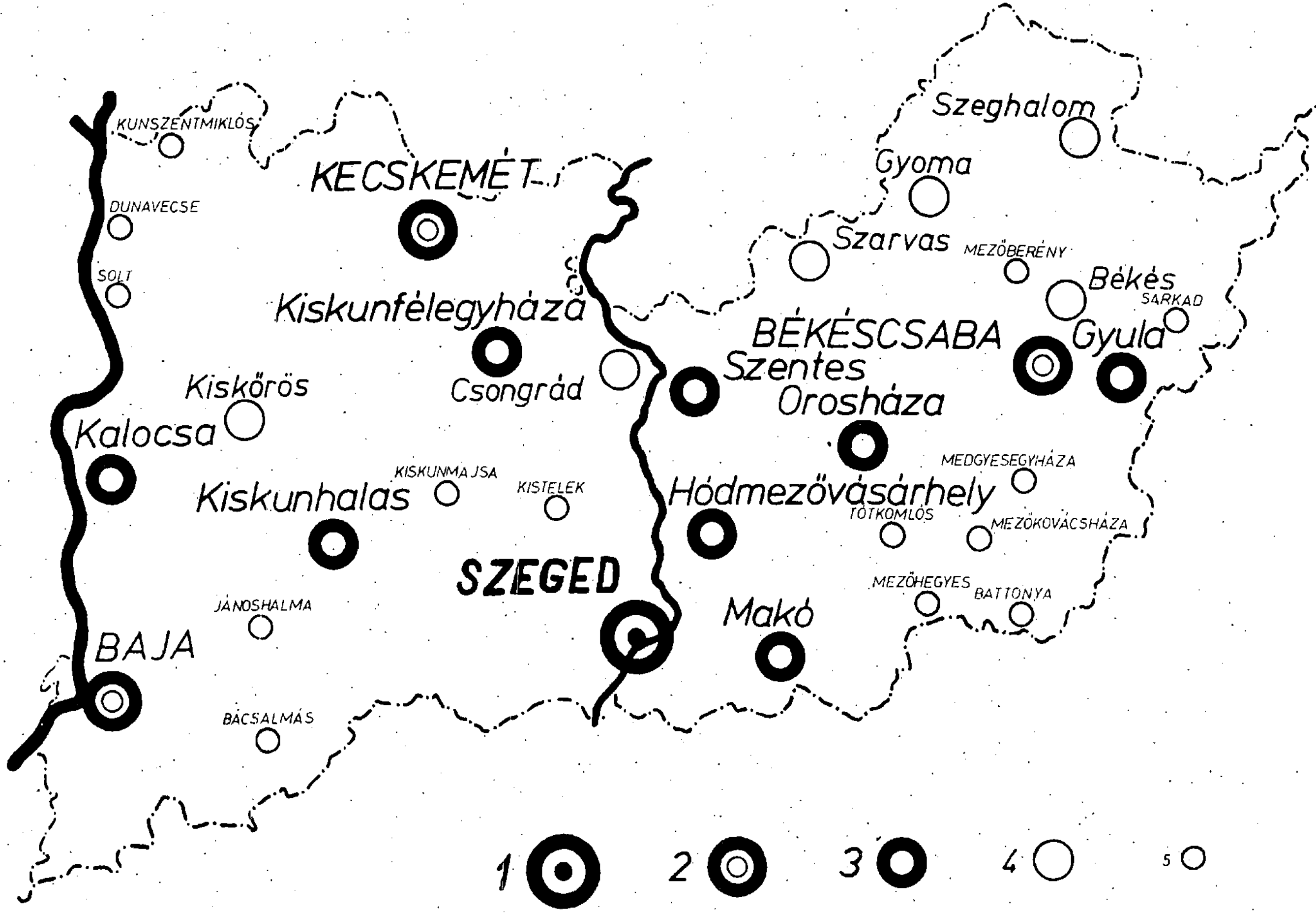


Fig. 1.: The hierarchic grades of the centers of the Southern Plain.
1 = regional center, 2 = paracenter, 3 = mesocenter, 4 = subcenter, 5 = microcenter

e) *Microcenters:*

They had no greater concentration of their share of population already in 1960. It is remarkable on the other hand that although their share of the total population and wage earners decreased, the ratio of industrial and building workers grew and by 1970 had approached the population ratio of the microcenters. The ratio of other wage earners also decreased only minimally (Table 5).

TABLE 5.
Share of the different-grade centers in the total and the particular section of the population of the Southern Plain

	Population		Wage earners		Industrial and building workers		Other wage earners	
	1960	1970	1960	1970	1960	1970	1960	1970
Reg. centers	6,65	8,13	6,46	9,03	14,77	13,89	16,64	16,09
Paracenters	9,86	11,49	10,16	12,23	17,89	18,09	17,83	18,67
Mesocenters	16,49	17,37	16,66	17,84	22,02	22,47	23,90	21,92
Subcenters	6,45	6,51	6,22	6,37	7,00	6,48	6,46	6,34
Microcenters	8,94	8,59	8,74	8,28	7,81	8,40	7,50	7,51
Total of centers	48,39	52,09	49,24	53,75	69,49	69,33	72,33	70,43
Other settlements	51,61	47,91	50,76	46,25	30,51	30,67	27,67	29,57
Total of Southern Plain	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0

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CHARACTERISTICS OF THE CHANGE OF TEMPERATURE IN RICE PLOTS OF VARIOUS DENSITIES

by

DR. ILONA BÁRÁNY and DR. J. BOROS

In rice-growing areas possessing different climatic features, the study of the microclimatic conditions of the rice plots is an important task. In addition to its theoretical significance, the practical importance of this is proved by the works of M. ZHAPBASBAEV (1969), V. K. VAMADEVAN (1971), N. P. KRASNOOK—V. PTASHKIN—Y. A. VISHNAKOVA (1971) and R. WAGNER (1966) referring to the correlation of the yield results and the climatic factors.

In our treatment, the microclimatic studies performed at Szarvas in 1971 under the direction of R. WAGNER were used as the basis of a comparison of the air and water temperatures of two rice plots of identical sowing density: a dense plot, which had been heavily treated with artificial fertilizer, and a rare plot, which had not been fertilized. The comparison was made using the extreme temperatures, the relative temperatures and the trigonometrical polynomials of the temperatures of the various levels.

The phenophases of the two plots in the months of July and August were as follows:

	Tillering	Development of stems	Development of panicles and flowering
Dense plot	Jul. 1—Jul. 21	Jul. 22—Aug. 1	Aug. 2—Aug. 31
Rare plot	Jul. 1—Jul. 19	Jul. 20—Jul. 31	Aug. 1—Aug. 31

In a study of the vertical temperature cross-sections of the rice plots (I. BÁRÁNY—J. BOROS 1972), it was found that in the various phases of plant development the temperature varies most significantly in the panicle level, and proceeding downwards from this the change of temperature is less in the periods of the development of the stems, and the development of the panicles and flowering.

The difference and phase shifts of the duration of the hot stage characteristic of the irradiation period and the cold stage characteristic of the radiation period can be seen from the relative temperature data expressed as percentages of the maxima obtained from the hourly mean values of the phenophases (Tables 1 and 2).

TABLE 1

Hourly relative temperature (in %) in a rice plot copiously treated with artificial fertilizer

Hour	Tillering					Development of stems					Development of panicles—flowering—maturation				
	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E
1	5	6	21	23	31	7	10	34	37	79	9	16	40	50	79
2	2	3	17	19	25	8	9	29	32	73	5	11	34	43	73
3	1	0	11	13	17	5	7	23	21	62	2	5	29	36	62
4	0	0	7	7	12	0	0	19	22	52	0	1	23	29	52
5	5	2	3	3	6	3	0	15	18	41	2	0	17	23	41
6	19	15	0	0	0	12	8	9	12	31	16	8	12	18	31
7	39	29	3	1	0	20	15	5	3	21	39	18	8	13	21
8	50	45	6	3	2	47	21	0	0	7	61	29	2	2	7
9	72	61	22	16	8	63	32	0	0	0	72	38	0	0	0
10	80	72	41	35	21	77	39	8	4	3	78	55	12	9	3
11	88	83	60	55	38	84	65	29	19	14	89	73	29	23	14
12	95	95	83	74	58	95	87	53	46	28	95	90	52	39	28
13	97	96	93	90	75	99	99	77	68	41	100	100	73	59	41
14	100	100	98	98	86	100	100	95	88	55	96	99	88	77	55
15	94	93	100	100	96	92	93	100	100	76	95	94	98	91	76
16	88	86	95	98	100	92	91	100	99	76	88	83	100	98	76
17	78	77	88	90	96	84	85	97	99	86	78	80	98	100	86
18	63	64	79	83	92	70	74	92	99	93	57	60	92	100	93
19	45	60	77	71	87	48	62	83	91	97	38	55	82	95	97
20	31	35	58	61	77	35	48	80	84	100	28	59	71	88	100
21	21	27	49	52	67	30	41	73	75	69	23	50	65	77	69
22	18	21	41	45	58	26	34	61	66	66	19	44	58	68	66
23	12	14	34	36	46	17	30	53	57	59	14	38	50	61	59
24	10	11	27	20	38	16	22	46	51	52	11	31	44	52	52

A = panicle level $B = 10$ cm above water C = 1 cm below water level D = middle of water
E = bottom of water

That part of the heating-up stage with a relative temperature of 70—100% in the various phenophases is delayed by 1—2 hours in both plots.

The difference between the air and water temperatures in both plots can clearly be discerned on the basis of the relative temperature. The difference in diurnal heating-up between the two plots is still small at the time of tillering. On the development of the stems in the dense plot the hot stage 10 cm above the water begins 1 hour later than in the panicle level, and lasts an hour longer.

With the thickening of the vegetative parts of the plant the shading effect increases, and this produces a change in the heating-up conditions of the 10 cm air layer and the water below it.

At the time of the development of the panicles and the flowering the temperature values reaching and exceeding 70% in the various levels from above downwards occur with a difference of 2 hours (a 1-hour difference can be observed only between the water level and the middle of the water).

TABLE 2

Hourly relative temperature (in %) in a control rice plot treated with artificial fertilizer

Hour	Tillering					Development of stems					Development of panicles—flowering—maturation				
	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E
1	10	10	18	18	21	6	7	23	23	29	10	10	30	36	58
2	5	5	9	12	14	5	7	20	18	23	6	6	24	29	47
3	2	3	7	7	9	3	5	14	12	16	3	3	18	24	37
4	0	0	2	3	4	0	1	9	7	11	0	0	13	18	29
5	9	8	0	0	0	2	0	5	3	4	2	1	8	13	21
6	26	21	2	0	0	17	8	0	0	0	18	9	3	7	13
7	45	40	9	6	5	35	26	3	0	0	43	26	2	4	8
8	60	55	19	15	13	50	40	5	1	0	61	48	0	0	0
9	72	69	47	22	26	60	53	10	7	0	70	65	8	5	3
10	79	75	53	39	43	70	65	23	20	7	78	75	27	24	18
11	87	81	69	69	60	78	73	41	38	20	87	84	50	44	37
12	91	90	84	83	77	89	88	65	61	39	94	94	73	63	58
13	96	98	95	95	92	95	98	84	81	61	99	100	87	80	74
14	99	100	100	100	100	100	100	97	97	80	100	100	98	92	84
15	100	100	98	99	100	99	98	100	100	91	99	97	100	98	92
16	96	97	91	92	96	98	92	99	100	95	92	87	98	100	97
17	88	87	82	83	89	93	74	93	96	100	83	74	90	96	100
18	76	74	73	73	80	76	54	87	89	97	65	55	81	89	100
19	54	52	63	62	71	51	41	79	74	93	40	39	71	82	97
20	36	36	52	51	59	39	38	72	71	86	31	32	63	72	95
21	26	25	44	42	50	34	30	62	63	79	24	25	55	64	90
22	20	21	35	35	42	17	24	55	55	70	20	20	47	56	79
23	15	15	27	27	33	22	24	45	47	61	16	16	40	49	70
24	11	12	21	21	25	18	20	40	40	52	11	12	27	40	60

A = panicle level B = 10 cm above water C = 1 cm below water level D = middle of water E = bottom of water

Similarly to what was observed at the time of development of the stems, at the bottom of the water there are high relative temperature values for a longer time prior to the maximum, and then immediately after the maximum the intense cooling down begins.

It is striking that the water begins to cool down with a 4—5, and sometimes even 6-hour delay compared to the air temperature. This delay increases with the progress of the phenophases.

Based on the courses of the relative temperatures, the developmental process of the plot climate occurs decisively at the time of development of the panicles and flowering.

From the isochrones of the maxima and minima (Figure 1 and 2) it can be stated that the minima occur later in the dense plot than in the rare plot. this being the more so in the dense plot than in the rare plot.
The times of the maxima and minima at the various levels are best differentiated at the time of development of the panicles and the flowering. At the panicle level and at 10 cm the minima occur earlier in this

period than at the time of development of the stems; this can be explained by the change of habit of the plant.

Proceeding downwards from the surface of the water, a delay of about 20 minutes can be observed in both plots. The isochrones of the maxima clearly show the differences in the plot. At the time of tillering

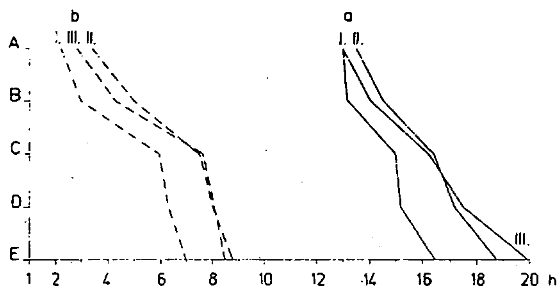

Figure 1. Isochrones of the extreme temperature values in the dense rice plot
I = tillering; II = development of stems; III = panicle development — flowering; a = maxima; b = minima.
A = panicle level; B = 10 cm; C = 1 cm below water level; D = middle of water; E = bottom of water.

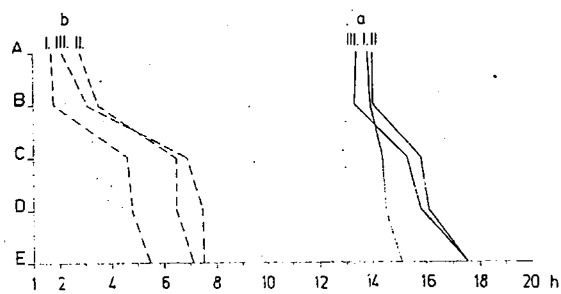

Figure 2. Isochrones of the extreme temperature values in the rare rice plot
I = tillering; II = development of stems; III = panicle development — flowering; a = maxima; b = minima.
A = panicle level; B = 10 cm; C = 1 cm below water level; D = middle of water; E = bottom of water.

in the rare plot, where direct radiation can penetrate into the plot without obstacle, the maxima are established in all the levels one after another within half an hour, whereas in the dense plot a period of 3 hours is necessary for this.

At the time of the development of the stems in the panicle level the maximum appears earlier in the dense plot than in the rare plot. From 10 cm downwards, however, the maximum can be observed earlier in the rarer plot. Similarly to the minima, the occurrence of the maxima is most extended at the time of development of the panicles and the flowering, this being the more so in the dense plot than in the rare plot.

Besides the times of appearance of the extreme temperature values, the differences of the values of the maxima and minima also develop in accordance with the plot climate (Tables 3 and 4). Only the maximum temperature was measured at the climate station, and the time of its occurrence was not recorded.

TABLE 3

Heavily fertilized rice plot

	Max. °C	Time hours	Min. °C	Time hours
		Tillering (Jul. 1—Jul. 21)		
A	25,7	$13^h\,00^m$	14,0	$2^h\,12^m$
B	24,8	$13^h\,12^m$	15,2	$3^h\,00^m$
C	25,0	$15^h\,00^m$	17,6	$6^h\,00^m$
D	24,8	$15^h\,12^m$	17,7	$6^h\,18^m$
E	23,0	$16^h\,30^m$	17,6	$7^h\,00^m$
F	24,8	—	14,3	—
		Development of stems (Jul. 22—Aug. 1)		
A	27,1	$13^h\,30^m$	15,5	$3^h\,24^m$
B	25,3	$14^h\,30^m$	17,0	$5^h\,00^m$
C	26,1	$16^h\,24^m$	18,3	$7^h\,30^m$
D	25,5	$17^h\,12^m$	18,2	$8^h\,00^m$
E	23,3	$18^h\,48^m$	17,8	$8^h\,48^m$
F	27,8	—	16,9	—
		Development of panicles and flowering (Aug. 2—Aug. 31)		
A	28,4	$13^h\,00^m$	15,1	$2^h\,48^m$
B	24,3	$14^h\,00^m$	17,1	$4^h\,18^m$
C	24,1	$16^h\,12^m$	18,8	$7^h\,36^m$
D	23,3	$17^h\,30^m$	18,9	$8^h\,06^m$
E	21,0	$20^h\,00^m$	18,3	$8^h\,30^m$
F	27,6	—	15,4	—

A = panicle level B = 10 cm C = 1 cm below water level D = middle of water E = bottom of water F = clime station

At the time of tillering in the two plots the phenophase centres of the maxima do not yet differ significantly. On the development of the stems the difference between the panicle level and 10 cm maxima increases, and at the time of development of the panicles and the flowering the difference is definite. During the development of the plant from 10 cm the activity level is gradually transferred to the panicle level. In accordance with this, at the time of development of the panicles and flowering the maximum is the highest at the panicle level in both plots. At 10 cm

TABLE 4

Unfertilized rice plot

	Max. °C	Time hours	Min. °C	Time hours
		Tillering (Jul. 8—Jul. 19)		
A	26,1	$13^h\,48^m$	14,8	$1^h\,42^m$
B	26,3	$13^h\,54^m$	15,0	$1^h\,48^m$
C	26,8	$14^h\,24^m$	17,8	$4^h\,36^m$
D	27,1	$14^h\,30^m$	17,9	$4^h\,48^m$
E	25,8	$15^h\,06^m$	18,0	$5^h\,30^m$
F	25,2	—	14,4	—
		Development of stems (Jul. 20—Jul. 31)		
A	26,4	$14^h\,00^m$	15,0	$2^h\,48^m$
B	26,5	$14^h\,00^m$	15,7	$3^h\,30^m$
C	26,0	$15^h\,48^m$	18,1	$6^h\,30^m$
D	25,9	$16^h\,06^m$	18,0	$6^h\,30^m$
E	24,0	$17^h\,30^m$	18,2	$7^h\,06^m$
F	26,5	—	16,1	—
		Development of panicles and flowering (Aug. 1—Aug. 31)		
A	28,5	$13^h\,24^m$	15,7	$2^h\,06^m$
B	28,4	$13^h\,18^m$	16,5	$3^h\,06^m$
C	25,7	$15^h\,18^m$	19,3	$6^h\,54^m$
D	25,0	$15^h\,48^m$	19,4	$7^h\,30^m$
E	23,0	$17^h\,30^m$	19,2	$7^h\,30^m$
F	27,6	—	15,5	—

A = panicle level B = 10 cm C = 1 cm below water level D = middle of water E = bottom of water F = clime station

and in the water the maxima are delayed and are lower. In all three phenophases the minima are lowest in the panicle level corresponding to the activity level.

The characteristics of the courses of the temperatures of the dense and rare plots, and within them of the different levels, are presented by means of the trigonometrical polynomials of the course of the average daily temperature in the various phenophases.

Similarly to other meteorological elements of continuous distribution, the compensated temperature courses can be depicted for all the phenophases from the characteristic data of the 24 and 12-hour waves of the temperature course (Tables 5 and 6) on the basis of the following relation:

$$y = K + a \sin \frac{2\pi}{T} t + U$$

where K = mean temperature (°C),
a = amplitude (°C),
T = 24 or 12 hours,
t = the current time, and
U = phase angle (°).

In the knowledge of the amplitudes and phase angles, a comparison is made of the 24 and 12-hour waves of the temperature below the water level and the 10 cm air temperature which well reflect the effects of the plot (Figures 3 and 4).

TABLE 5

Characteristic values of the trigonometrical polynomials in the heavily fertilized rice plot

		A			B			C			D			E		
		K	a	U	K	a	U	K	a	U	K	a	U	K	a	U
I.	$\frac{2\pi}{24}$	19,3	5,6	249	19,5	4,7	240	21,0	3,3	211	20,9	3,2	205	20,1	2,6	187
	$\frac{2\pi}{12}$		0,6	90		0,6	84		0,8	30		0,8	30		0,5	0
II.	$\frac{2\pi}{24}$	20,7	5,5	240	20,7	3,9	222	22,0	3,4	183	21,7	3,2	180	20,5	2,5	154
	$\frac{2\pi}{12}$		0,9	69		0,8	45		1,0	12		1,0	8		0,5	57
III.	$\frac{2\pi}{24}$	20,8	6,4	249	20,3	3,3	229	21,3	2,3	183	21,0	1,9	172	19,8	1,2	135
	$\frac{2\pi}{12}$		1,0	87		0,7	63		0,8	9		0,5	27		0,2	15

A = panicle level B = 10 cm C = 1 cm below water level D = middle of water
E = bottom of water K = mean temperature (°C) a = amplitude (°C)
U = phase angle (°) I = tillering II = development of stems III = development of panicles-flowering

The difference of the amplitudes between the 10 cm and the water level in the case of the 24-hour wave was the greatest in the panicle development — flowering stage in the dense plot. In no phase, however, does the difference exceed 2 °C. In contrast, in the rare plot this difference is more than 3 °C in all three phenophases. The greatest is 5.8 °C at the time of panicle development — flowering. In accordance with this, the phase delay in the appearance of the maxima also increases here.

TABLE 6

Characteristic values of the trigonometrical polynomials in the unfertilized rice plot

		A			B			C			D			E		
		K	a	U	K	a	U	K	a	U	K	a	U	K	a	U
I.	$\frac{2\pi}{24}$	20,2	5,6	253	20,2	6,1	241	21,9	4,2	222	22,0	4,2	220	21,5	3,6	213
	$\frac{2\pi}{12}$		0,3	60		0,4	45		0,8	60		1,0	51		0,8	36
II.	$\frac{2\pi}{24}$	20,3	5,5	237	20,5	5,3	229	21,8	3,6	195	21,8	3,6	192	20,9	2,8	176
	$\frac{2\pi}{12}$		0,5	45		0,8	51		0,8	15		0,8	15		0,3	45
III.	$\frac{2\pi}{24}$	21,3	6,3	245	21,6	5,7	253	22,2	2,8	199	22,0	2,5	187	21,2	1,8	172
	$\frac{2\pi}{12}$		0,7	75		1,2	69		0,9	18		0,7	9		0,3	6

A = panicle level B = 10 cm C = 1 cm below water level D = middle of water E = bottom of water
K = mean temperature (°C) a = amplitude (°C) U = phase angle (°)
I = tillering II = development of stems III = development of panicles — flowering

There is no substantial difference between the amplitudes of the 12-hour waves, but the delay is greater in the rare than in the dense plot.

From examination of the relative and extreme temperature values it can be stated that the features of the plot climate are convincingly reflected by the difference between the heating-up of the 10 cm and the panicle level with the transfer of the active surface to the panicle level in the irradiation stage.

It may be said that as a result of the heavy fertilization the vegetative parts of the plant begin to develop rapidly, and because of the large mass of leaves the active level is found in the panicle level (the most closed part of the leaf zone) both by day and by night; as a consequence of this the diurnal course of the temperature will be the most extreme here, while the temperature course is more balanced in the levels below the closed leaf zone and in the water.

The temperature of the rare control plot, however, resembles that of the free water surface, as regards both the daily courses, and the sizes and the times of occurrence of the extreme values.

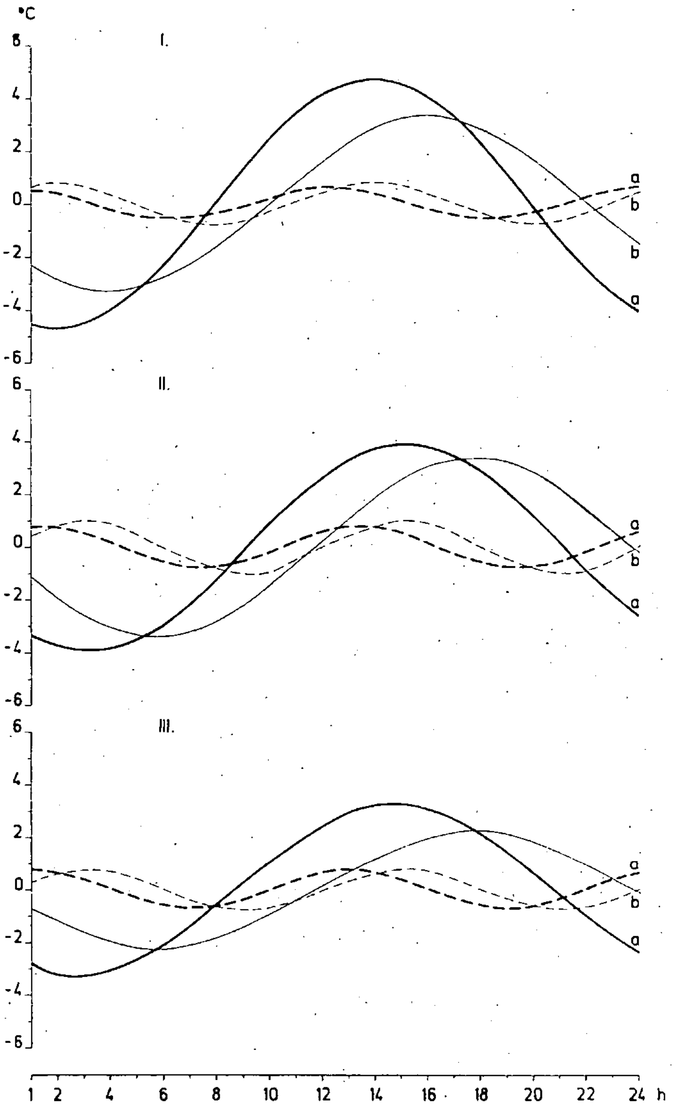

Figure 3. 24 an 12-hour waves of the trigonometrical polynomials in the dense rice plot
I = tillering; II = development of stems; III = panicle development — flowering; a = 10 cm; b = 1 cm below water level.

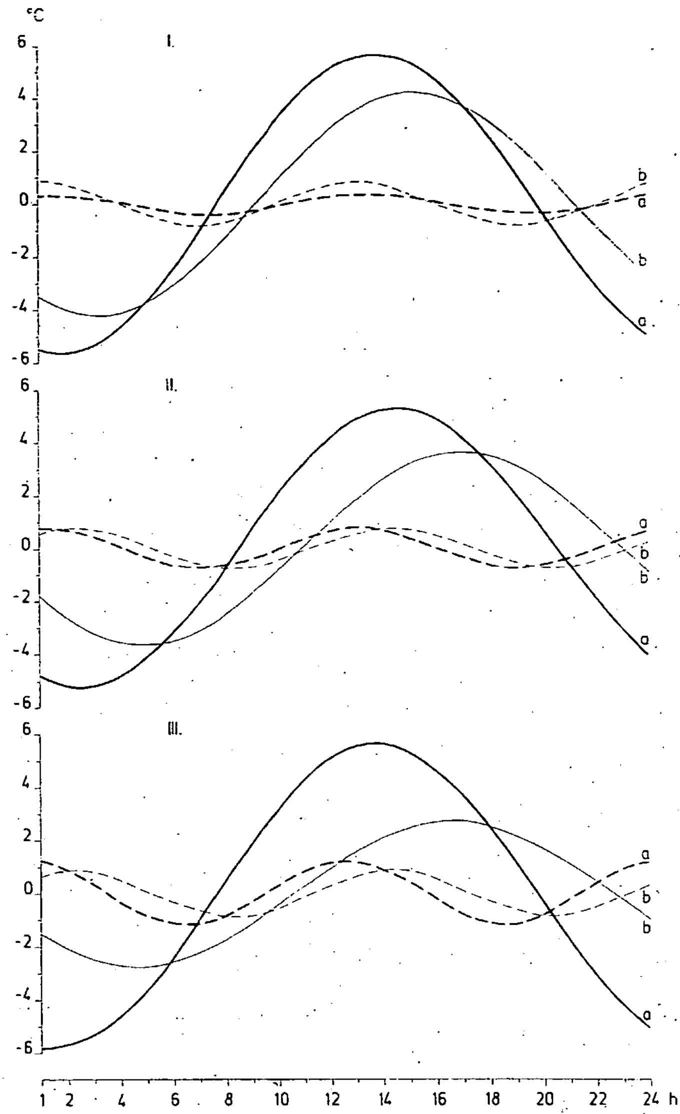

Figure 4. 24 and 12-hour waves of the trigonometrical polynomials in the rare rice plot
I = tillering; II = development of stems; III = panicle development — flowering; a = 10 cm; b = 1 cm below water level.

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ON THE METHODS OF REGION RESEARCH WITH SPECIAL REFERENCE TO THE SOUTHERN GREAT PLAIN OF HUNGARY

by

DR. J. JUHÁSZ

During the last two centuries the forces of production of the socialist countries have experienced a great development as a result of planned cooperation. According to Mikhailov "effective and reasonable utilization of the natural resources has become an important task in the development of the different countries as well as of the whole socialist camp" (1). Consequently, *regional division* of the countries of *Central and Southern Europe* on the basis of common principles in an important task of the present and the nearest future.

Mikhailov attempts a comparative study of the regions and physical geographic regional division of the Soviet Carpathians and the Ukraine and of Hungary (1). The Soviet geographers theories on regions are well known. Through the works of Mikhailov and his associates we have had an opportunity, although only later, to get acquainted with the fundamental theoretical and methodical problems studied by the Ukrainian geographers. We think that these methods provide very good possibilities for the study of the physical geographic classification of our regions.

Some theoretical and methodological principles for the study of regions

Dokuchaev, Berg, Bulla, Zólyomi and their followers defined in their studies (on territorial units) the theoretical basis of physical geographic region research.

According to Berg the region is a physical geographic territorial unit, while Kalesnikov precises the definition by naming the dimensions. According to Kalesnikov the region is a relatively homogeneous area formed in a natural way in the course of its paleographic and historical development and differing from other regions in its structure, i.e. in the correlations and interactions of the different geographic factors, in the particular combination of the smaller territorial units constituting the region, and special features of the rhythm of the seasons (2). *The difference between two or more regions lies in their lithological characteristics, surface, climate, waters, soil, flora and fauna;* the physical geographic unit is determined by the particular structure and development of these elements.

However, the power of the different factors is different and so they can be classified. According to this classification the lithogenic and hydroclimatogenic factors are *strong*, the biogenic factors relatively *weak*. As lithogenesis is the most resistent, Isachenko's statement that "the period of existence of the region can be defined in geological terms" is correct According to Gerenchuk the geomorphological complexes can be defined from the types of soil and the flora; he suggests that delimitation of the regions should be made on the basis of the river valleys, and top [rock] formations (3).

The geological base is generally the same over the whole of the region; in the transitional areas different, modified geological conditions are found. Thus different formations occur already at the boundaries of the different regions. According to Solntsev the geographic region is a system consisting of smaller physical geographic spatial units developed according to the laws of nature and possessing morphological structure (4).

It has been demonstrated that the most important features of the region are expressed in the structure. The differences between two contiguous regions can be demonstrated with the help of the ratio of morphological differences. The morphological structure is visible and can be represented cartographicaly (3).

The Soviet region researchers, for instance, are investigating the area of southeast Ukraine in three morphological structures: facies, urochishche and mestnost'.

Facies is a smaller part of the region that develops in a particular area: identical *lithogenic composition, humidity conditions, microclimatic and soil conditions, and a particular flora* with its fauna.

The basic region unit as a facies may be determined by the vegetation, for different types of flora can be the dominant factor on the slopes, dry river channels, and terraces of the mesorelief. Human activity can influence first of all the biogenic factors. On the basis of changes of the soil and the vegetation cover, dominant and subdominant facies can be distinguished (4). In the course of studying the facies, mapping of the areas under investigation became necessary. For greater distinctness detailed maps, sometimes with 1 : 500 and 1 : 1000 scales, should be made.

The *urochishche* is the highest form of the mesorelief characterized by a particular *rock composition, type of soil* and *vegetation cover*.

According to some researchers the urochishche is made of genetically similar facies (3). Soviet researchers call the repeated urochishches *basic urochishches* that determine the basic structure of the region (4). The term *"dominant urochishche"* can often be used instead of "basic urochishche"; consequently the areas not ensuring the basic structure of the region are *"subdominant urochishches"*. Both types of urochishche have their own economic importance; these areas are well delimited by natural boundaries such as rivers, forests, foothills, etc.

Gerenchuk proposes anthropogenic boundaries such as plowfields, meadows, pastures, forests, etc. between the cultured areas and the areas in which no substantial or qualitative changes can be observed. They can be mapped well using a scale of 10.000 to 1000.000.

The *geographical mestnost'* is a new notion. It is a relatively larger, genetically uniform area of the region, characterized by a homogeneous geological basement, local climate, and identical formations (3). The regions in general contain several urochishches. Maps on the 25.000—100.000 scale are suitable to represent them.

The elements of region typology, the facies, the urochishche and the mestnost', are combined into a unit by their development history and their local natural processes. The units of the natural processes become the center of interest of the investigation on account of considerations, on the basis of which perhaps higher categories can also be estblished. We can mention here that the Ukrainian region researchers regarded the "oblast' " (geographic area), the "provintsia" (geographic province), the "zona or strana" (physical geographic region) as higher, larger units. *"Oblast' "* means a relatively large territorial unit of the region bound together by common historical development, climate, and vegetation cover. It must be mentioned at the same time that the Ukrainian region researchers use further differentiation within this territorial unit. The territorial units ara characterized by a common climate, identical soil,, and the same plant association. The combination of several physical geographic "oblast's" creates the (physical geographic) "provinces" which are larger territorial units than the "oblast' ". Here, too, investigations can be carried out by different methods; the basis of such investigations can be the particular geographic location, the climate, the vegetation, the horizontal position of the soil, and the vertical arrangement of various factors. Differentiated division obtains in this larger territorial unit as well as in the "oblast' ".

The physical geographic division and study of different regions at home and abroad is based on the principle of complex physical geographic characterization. Determination of different basic units is made on the basis of complex examination of the geographic factors (5, 6, 7, 8).

Delimitation of areas, division into regions, is based on the study of common physical geographic processes. No other special investigations working within such a narrow field could replace this study. While the different special disciplines investigate the single links of the complicated processes *the task of geography is to clarify and explain the structure and mechanism of the region* (5).

The distinctive *character of the region* is determined by its historical past.

The *genetic investigations* determine the age of the region and the phases of the development of its present form. The results of these investigations facilitate the classification of smaller units into larger territorial units.

The methods most recently used in region research are:

The *comparative method,* in which the elements of the physical geographic units are compared one by one. At the same time similar processes and the geographic laws prevailing in a given area are identified.

The *selective comparative method,* in which two or three important factors — temperature, humidity, etc. — are considered specially for comparison, and by means of which the geographic processes can be evaluated qualitatively.

The *method of dominant factors,* in which the dominant factors are ascertained and throughly studied. No comparison is possible because the dominant factors are different in different areas.

The boundaries of the territorial units can be determined by the factors that show the most characteristic features of the region under consideration.

In all cases it is necessary to *study the terrains* before defining the territorial units. This is followed by working up of the measurement data collected and finally the conclusions.

Various methods of investigation have been used for regional studies (1). Differently from the methods developed so far, in our work we have studied such connected elements in areas of different orders of magnitude as can be representative of cultivated areas conditioned by the now existing genetic soil types. The main genetic soil types as well as the different climatic elements are suitable for differentiating the basic region units or mosaics within connected areas and for delimiting physical geographic microregions.

As the characteristics structure of the regions is determined by its historical development, it is advisable to consider the present form of the region from the point of view of its stages of development. Therefore we are going to describe the surface — near layers of the Southern Plain in broad outline with special regard to the formation of region units.

From the point of view of the *development of the Pleistocene layers and the surface,* the Southern Plain is divided into: 1. the valley of the Danube; 2. the quisksand and loess plain in the Danube—Tisza interfluve; 3. the valley of the Tisza; and 4. the Trans-Tisza region (9).

From the point of view of the whole region system the influence of the surface-near layers on the development of the surface layers, their composition and settlement pattern, is of decisive importance.

For the sake of completeness we must mention in certain respects the deeper lying sediments of the basin. The bulkiest, about 2000 m thick sediment among the layers filling the basin of the Great Plain settled at the time of the Pannonic stage in the salt water of a landlocked sea (1, 2, 3). The composition of this basin is homogeneous, consisting of clayey marly layers. On the other hand the Levantine layers of the Pliocene are freshwater sediments. At the time of Levantine sinking, in consequence of the rapidity of sinking, the main mass of sediments was coarse fluviatile deposits that form the water reservoirs of the artesian layer.

After the Pannonic stage the southern part of the area sank unevenly. The center of the subsidence was in the area of Szeged where the Levantine layer can be found as deep as 1000 m. In all directions away from the center the Pannonic layer rises considerably (1). The subsidence and filling up of the Great Plain did not coincide with the movement of the Levantine layer. The Pleistocene layers are the thickest in the angle of the Körös rivers. This region was in the geological past the most intensely sinking area (13). It can be said of the whole of the Trans-Tisza region i.e. the plain east of the river Tisza, that its sinking in the Pleistocene was more considerable than in the other parts of the Great Plain. The sinking influenced the subsequent development of the surface-near layers.

To the surface-near formations belong the *uppermost Pleistocene* and *Holocene deposits.* The surface-near formations can be divided into two groups: surface formations and layers under the surface formations.

Under the surface formations there is *driftsand,* especially in the area of Kecskemét and southeast of it a wider expanse in the area of Kiskunhalas and south of the latter. *Gravelly sand* is found 30 km south of Békéscsaba, in the same latitude as Hódmezővásárhely, over an area of about 200 sq. km. *Fluvial sand* prevails over the larger part of the Trans-Tisza region with the exception of the areas of Hódmezővásárhely and Orosháza and a 30—40 km wide area south of the Körös where the soil layers contain *sandy silt.* In the Danube—Tisza interfluve, especially along the Danube and in its middle portion, loess, on the right bank of the Tisza a mixture of sandy silt and loess dominate (Fig. 1).

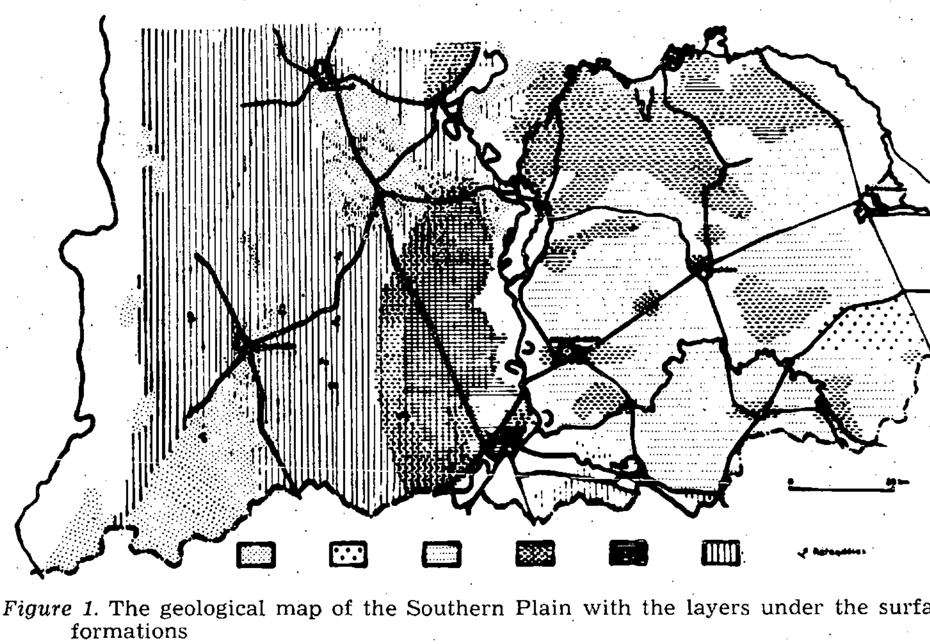

Figure 1. The geological map of the Southern Plain with the layers under the surface formations

As regards the surface formations, there is *dry-land loess* over the drift-sand of Kecskemét and Kiskunhalas, *loessial sand* over the gravelly area of the Trans-Tisza region, *infusion loess* and in places *silty and sodic* *loess* over the fluvial sand ant the clayey sand Over the loess and clayey silt of the Danube—Tisza interfluve *drift-sand* can be found where loess is concerned, and *infusion loess* where clayey silt is concerned (Fig. 2) (9).

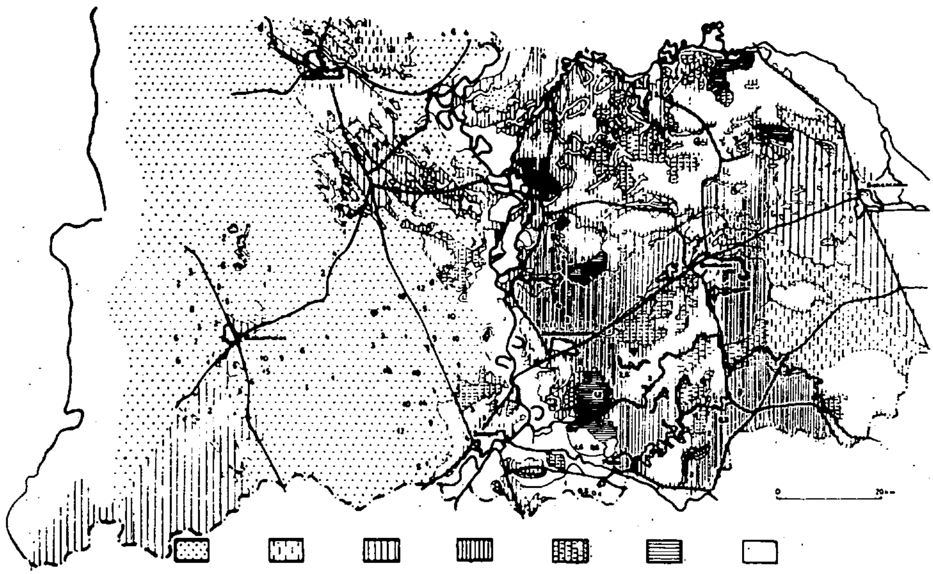

Figure 2. The geological map of the Southern Plain with the surface layers

In the study area the basis of the classification of the whole landscape system is the development of the Pleistocene layers and the layers under the surface formations.

The valley of the Danube

The valley of the Danube is a relatively wide tectonicerosive depression; from Dunaföldvár to Kalocsa it is narrow, widening suddenly further south; its average width is about 20 km. Miháltz and his coworkers demonstrated that the deposits are increasingly finer nearer the surface (Fig. 3).

The uppermost three meters generally consist of a mixture of *clay and clayey silt;* under this there is a 3—4 m thick layer of very fine sand and in some places *silty sand.* From 7—8 m depth down there is a 12 m thick layer of *fine-grained and medium-grained sand,* then below 20 m depth a 2 m thick layer of *silt,* and lower down a mixture of *fine-grained* and *coarse-grained sand* as dominant soil types.

The valley of the Danube is cut in the thick layer of medium-grained sand and filled up below by small and fine-grained sand. The steepness of the river-bed has developed not only under the influence of erosion but it is also tectonically determined. The present topmost aleurite layers of the valley that cover the surface to a depth of 1—2 m derive from the *Holocene* period. A large portion of the surface of the valley is covered by highly calcareous alluvial silt which is similar to loess, but the fraction

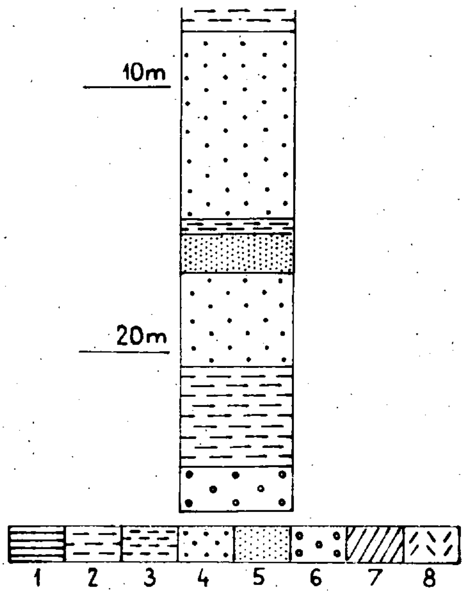

Figure 3. The layer seeuence of bores in the valley of the Danube (after Miháltz)

characteristic of loess cannot be demonstrated in it. Its water permeability is minimal: 10^{-7}—10^{-8} cm/sec. In the period of the Older Holocene, isolated drift-sand hills formed in some places, for instance in the area of Hajós. The area of Gyón is characterized by the division of the alluvial silt into two parts, while the final stage of the filling up of the riverbed near Kecel and Szabadszállás is attested by the formation of peat (14).

In the plains between the sand dunes Younger Holocene *alluvial silt* can be found which is younger than the sand. A few meters deeper there is in places also Older Holocene alluvial silt on which the drift-sand deposited.

The thickness of the silt layers generally varies between 2 and 8 m; in the higher lying places it may be 2—3 m, in the abandoned river channels 6—8 m. There are areas in which the depth of the silt layers does not exceed even the depth of tilling. Where the alluvial sand is near the surface, it makes irrigation farming possible because of its high water permeability.

The surface formation of *the alluvial silt of the Danube* is yellowish grey, in some places the inverse, which on account of its highly crumbly nature has been mistaken for loess, but the fineness of its grains has decided the question of its origin (15). In the deeper lying areas it has become alkalized, but in these places its surface forms a water-impermeable layer.

The platform of the Danube—Tisza interfluve is an area with diversified surface. It rises 30—40 m above the valleys of the Danube and the Tisza. Earlier the whole platform was considered to be the Pleistocene deposit of the Danube (B. Balla and J. Sümeghy). However, Miháltz and his coworkers, on the basis of their investigations lasting several decades, drew the conclusion that there are no alluvial deposits at all on the platform of the Danube—Tisza interfluve (14, 15, 16). The whole area, excepting the lower lying parts near the rivers, consists of drift-sand, loess, and their modifications. Molnár and co-workers examined and analyzed the material gained from borings in the line of Baja and Szentes and found that all the bore materials indicated an eolic origin (16).

The maps made by the Geological Institute in 1950 show the Danube—Tisza interfluve accurately. The geological profiles of the bores show that down to 30 m in the western and central parts there are six *loess layers* separated from each other by drift-sand and humus-containing loam. In the eastern and southeastern areas the loess layer thins out, even disappearing in some places where Pleistocene drift-sand appears instead. In fact, the thickness of the drift-sand layer reaches even 10 m in some places between Kistelek and Pusztaszer.

The loess layer can be found not only in the profiles between Baja an Szentes but also in sample cores from the area of Kecskemét and Félegyháza (14, 15).

Sediments deposited by the Danube can be found in the valley of that river. The drift-sand layers also owe their origin to the Danube because the west winds have drifted the sand of the Danube on to the territory of the platform plain.

East of Kecskemét as far as Kécske alluvial deposits are found with silt on their western margins and clay on their eastern edges instead of the deeper loess and drift-sand layers. It can be demonstrated from the sand that these are deposits of the Tisza and its tributaries.

In the Danube—Tisza interfluve the Pleistocene sediments are divided into two parts: the larger, western part is an accumulation of wind-driven deposits, where there is drift-sand under the top layer of loess; the smaller area is the inverse of this. There is no water-impermeable layer in the whole area, with the exception of the limy parts. In the much lower eastern part bordering on the valley of the Tisza there is water-impermeable clay, clayey silt, or slightly permeable silt with fine sand under the loess. The extension of the clayey sediment under the loess is rather variable, e.g. in the area of Csongrád the loess based on drift-sand extends as far as the Tisza, while in the area of Szeged there are clayey sediments under the loess. The surface formation is drift-sand. There is a thick layer of Holocene drift-sand at the western edge of the platform plain as for example in the areas of Illancs, Kiskunhalas, Soltvadkert, Ágasegyháza, and Örkény. The Holocene drift-sand thins out in the eastern half of the platform but in some places it extends over the eastern edges of the Trans-Tisza region; such a surface can be found also between Cibakháza and Kunszentmárton. Loess can be found on the surface southwest of the Kiskunhalas—Kelebia line as well as in the areas of Kecskemét, Kiskunfélegyháza, Pusztaszer, Csongrád, and Szeged (9).

The oldest among the surface formations is the Pleistocene drift-sand which underwent rearrangement during the Older Holocene; the varieties of loess were deposited on this. The varieties of loess are the last formations of the Pleistocene on which the drift-sand of the Older Holocene settled (9).

The basic items of proof are the following: The situation of the flat settlements shows that a carrying medium of vast expanse, as for example air, can form such a flat area of a homogeneous material. Gravel and clay do not occur in the layers. The size of the grains, 0.02—0.06 mm, invariably indicates loess.

The notions of "blue clay" and "blue sand" can be explained in light of the examples by the fact that the layer that has got under the surface in time becomes bluish gray if it gradually sinks below the level of the subsoil water.

The grains of sand are classified according to the different degrees of abrasion on the basis of which their eolic origin can mostly be verified (Fig. 4).

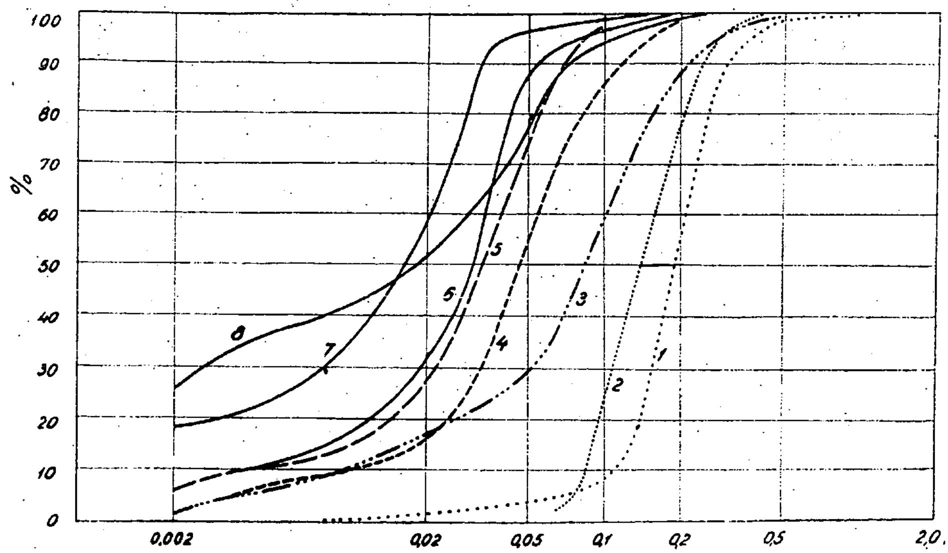

Figure 4. Graphic comparison of the grains of wind-blown sands and varieties of loess (after Mihältz)

Andor Horváth demonstrated that only *ubiquitous land snails of groves* can be found in the sand layers of the Danube—Tisza interfluve. Not one fluvial kind can be found in the material of the samples. At the same time Mihảltz's statements are confirmed by the results of Horváth's investigations (14, 17).

According to the detrital cone theory *the depressions in the territory of the platform* are remainders of one-time channels of the Danube. In this case their sand should be of fluvial origin or should contain sharp-edged grains at least in traces; in the absence of such features, however, an eolic origin can be proved. Furthermore it can be ascertained from several hundred bore samples taken by Mihảltz and co-workers along a NW—SE line that there are eolic layers down to 150 m depth. The results of Artesian bores also support this.

The movement of the sand on the surface is controlled by the prevailing nortwestern wind. The composition of the platform plain suggest that the Danube may have inundated the lower — lying areas many times.

The flood — basins of the Danube and the Tisza can well be distinguished from the Pleistocene and Pliocene formations (16).

In the Older Holocene the drift-sand moved much in the territory of the platform. This phenomenon can be traced back to the warm and dry *hazel-nut phase.* In the depressions of the drift-sand deposition of carbonate brought from the higher-lying parts by the soil water is common. The covering humus-containing deposits can be traced back to beech phase 1 on the basis of pollen examinations, while more recent movements of the drift-sand can be traced in beech phase 2.

The Tisza River valley

The eroded depression sank till the last phase of the Pleistocene and then it was filled up mainly with fluvial deposits. It has been ascertained on the basis of Mihảltz's core samples that the Pleistocene layers slope toward the Tisza. As a result of its structure, the high-lying part of the platform consisted to a considerable depth of eolic sediments, its lower part on the other hand was formed of fluvial deposits. The area is of varying extent. In the area of Tiszakécske the depression does not reach 5 km in width, while toward the south and the border of the country it extends gradually, reaching in places 25—30 km width.

In the lower parts the loess is often alkalized but in many places it is covered by flood mud. In the lower parts of the whole layer fine grains are common. On the edge of the platform a water-conducting sand layer stretches toward the Tisza valley in 15 m depth. The movement of the subsoil water is ensured, water-impermeable layers do not occur above 30 m depth. At smaller or larger distances the sand layer is in direct contact with the loess layer. The deeper layers also slope toward the river valleys (9).

During the Pleistocene period the Tisza river valley was constantly sinking, the river-bed was constantly changing, and its deposits were frequent. Further north the depression of the Tisza was about 20 m at Szeged, 15 m at Algyő, and 10—15 m on the average at the beginning of the Holocene. In the lower part of the washed-out depression there is a coarse, loose sand layer becoming finer upward, aleurite, clay, and finally meadow clay. The Pleistocene terrain of the Tisza River valley is covered by Holocene *alluvial silt* at the lowest places. The floods have deposited here a 1—2 m thick fine silt layer. Such a formation can be found in the area of Algyő. Here the width of the alluvial silt is nearly 3 km.

Occassionally the clay layer may be missing and the young alluvial silt may be sandy, especially near the river. On the basis of Miháltz's bores in the areas of Makó and Szentes it can be stated that "the thickness of the quaternary layers is at least 160 m at Makó and at least 200 m at Szentes" (14). There are also sunken loess and sand layers here buried under fluvial clay. The sand layers are of fluvial origin, the clay is generally of aleurite fineness with a high carbonate content, thus differing markedly from the other sediments.

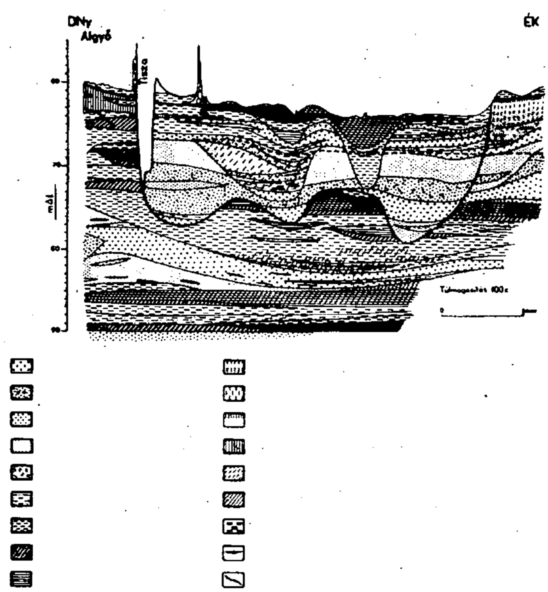

Figure 5. The hydrological profile of the Tisza River valley at Algyő (after Miháltz)

Farther away from the river, as in the case of the formations of the Danube-Tisza interfluve as well as in the area of Baktó and Sártó and extensive areas of the Trans-Tisza region, deposits of meadow clay over the loess are frequent.

The Tisza River valley was cut in the Pleistocene layers at the beginning of the Holocene epoch. The Tisza of the Holocene epoch eroded and filled up 5—10 km wide areas with its meanderings. In spite of this it is lower than the surrounding Pleistocene areas. Investigations prove that the Holocene erosion removed the Pleistocen layers to a depth of 15 m, and south of Szeged to a depth of 20 m (Fig. 5).

Filling up of the eroded valley began with smaller medium-grained sand (0.1—0.2 mm ∅). Higher up the ratio of fine sand, silty fine sand, and sandy silt increases. The youngest beds are filled with sandy silt, clayey silt and on top with meadow clay. Meadow clay covers most the areas near the Tisza in thinner or thicker layers. The meadow clay is sporadically replaced by sedimentary alluvial silt.

The development of a water-impermeable layer at the surface depends on the thickness of the meadow clay. It is of frequent occurence, however, that the meadow clay is covered by Holocene alluvial silt at the surface. It has been ascertained that neither the alluvial silt nor the meadow clay "fit into the closing accumulation cycle and was deposited owing to changed conditions" (9). The alluvial silt formed in the last phase contains more sand near the riverbanks; their structure is partly modified depending on their distance from the rivers. Yet the surface structure so formed cannot be said to be uniform because there are sequences of layers in the accumulation phase in which the clayey layers are missing and their place is filled by the silt deposited on the sand layer.

The Trans-Tisza region

The whole region cannot be differentiated from the Tisza river valley. Its surface slopes toward the Tisza; its surface is covered by loess and and fluvial sediments. The fluvial sediments are in part Pleictocene loess or the filling of abandoned channels.

The loess is generally wet land loess, in some places bog loess. The low-lying areas are often alkalized (Fig. 6).

Alkalized and loessial areas in the Trans-Tisza region

The thickness of the loess varies between 2—4 m. The fluvial filling up finished at the time of the formation of the valley with the erosion cycle. Fine sediments deposited which at the same time meant the end of the accumulation cycle.

The rivers arriving in the plain deposit coarse debris, on the basis of which the different layers can well be distinguished. The river water carrying the coarse sediment had a great power that was able to cause erosion even at the stage of filling up. At a later stage the occurrence of finer-structured parallel or lentiform layers is more frequent.

Miháltz distinguishes five cycles in the fluvial sediments of the Trans-Tisza region (18). Under the loess there is generally sand of varying composition. Besides the dominant role of wet-land loess there is dry-land loess to the north and northeast of Orosháza as well as at Makó, Szőreg and to the east of Mindszent. The dry-land loess was in all cases deposited on wind-blown sand. In the Trans-Tisza region in spite of the large amounts of surface loess there are remarkable qualitative differences which underline the importance of the investigation of the formations under the surface.

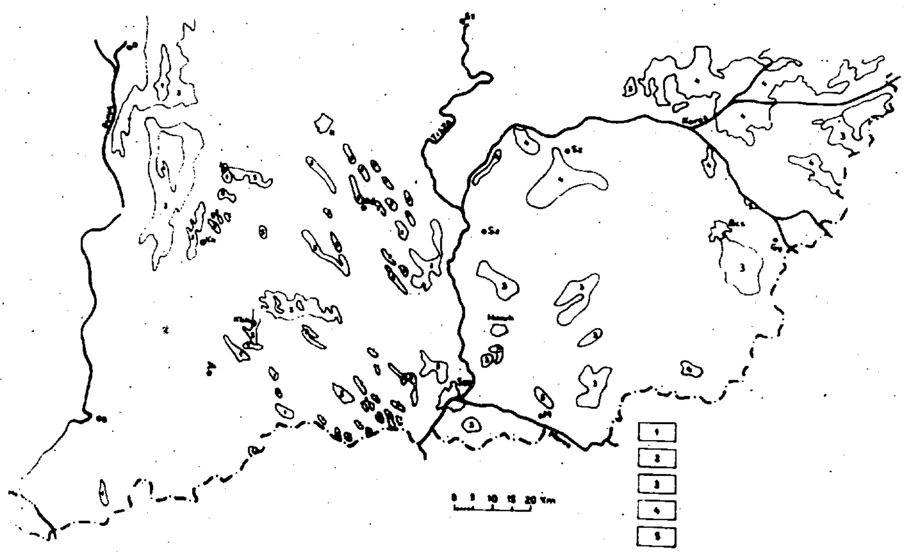

Figure 6. The angle of the Tisza and the Körös

The western half of the area cannot be distinguished structurally from the Danube-Tisza interfluve. The dry-land and wetland loess was deposited on drift-sand. This sand occurs also on the surface in the middle of the area. Under the drift-sand there is another layer of loess. In the eastern half of the area infusion loess occurs together with sodic soils which, however, play only a secondary role. Under these there are silt and clay layers.

The lowland south of the Hármas- (or "Triple") Körös

The larger part of the area is covered by silty loess; in the lower central parts sodic and clayey loess is dominant. The largest sodic areas of the Trans-Tisza region are there. The low-lying parts were mostly covered with stagnant waters already in the Pleistocene, more exactly at the end of the Pleistocene. Around the sodic areas at the time of the formation of loess the silt of floods mixed with the falling dust, the result of which was the formation of loesscontaining silt. Clayey flood silt of minimal thicknes deposited on the surface of the quaternary flood deposits. In the depressions of the river-beds there is meadow clay and humus-containing silt. Similar humic clay covers the surface of sodic soils. In the whole area *silt and clay* occur predominantly under the loess; only west of Szarvas and Kondoros is there sand instead.

The rolling plain of Békés and Csanád

The sand and the dry-land loess of the rolling plain have been transported here by the wandering rivers of the area. This means that the area bordered by the Tisza, Maros, and Körös rivers is an alluvial fan. Its highest part is the gravelly coarse sandy area between Kevermes and Kétegyháza. Near the Körös and the Tisza rivers silt clay layers are found. In the inner areas the there is a sequence of gradually finer layers under the loess. It should be noted, however, that an alluvial fan can also be found on the southwestern edge of the Tisza region which in all probability originates from the Maros and which was probably divided in two by the Holocene incision of the Tisza. The alluvial fan is generally covered by loess, partly by loess-containing fine sand, and partly sandy loess. The thickness of the covering layers which are exposed to constant change is highly variabla.

The plain of the region of the Maros

This plain comprises the area between Hódmezővásárhely, Orosháza, and Mezőhegyes. The underlying layer of the loessial part is sand or clay. The loess of the surface is wetland loess with sodic soils with no run-off in some places. In the region of the Maros there is dry-land loess, and toward the east in the area of Csanádpalota loess deposited on a long range of riverside dunes is found. The surface of the area is rather varied; in the lower-lying parts meadow clay of great expanse can be found which stretches from Deszk to Hódmezővásárhely.

The rolling plain of Békés and Csongrád

This is an area stretching from the Hódmezővásárhely — Békéscsaba line to the Szentes — Mezőberény line. The loess outcrops in two bands along the riverside dune ranges: one between Nagyszénás and Szentes, the other between Hódmezővásárhely and Orosháza. These ranges probably originate from the Maros (9). It has been ascertained that the Pleistocene river-beds were transformed by Holocene rivers in the places where the covering layer is mostly humus and meadow clay. Riverside dune sand can be found in large areas, but not on the surface but mostly with a covering layer of loess-containing sand or dry-land loess. Alkalization occurred in the riverside sand dunes. In the mineral composition of the underlying layer clay and silt can be found besides sand. In the lower parts between the sand dunes chiefly dry-land loess can be found (9).

The structure of the landscape can be studied on the basis of a short characterization of the soil layers at and under the surface revealing their distinctive character and geological past. The elements of landscape typology can be examined in terms of their historical development and natural processes; at the same time there is the possibility of differentiation within the areal units on the basis of their characteristics.

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